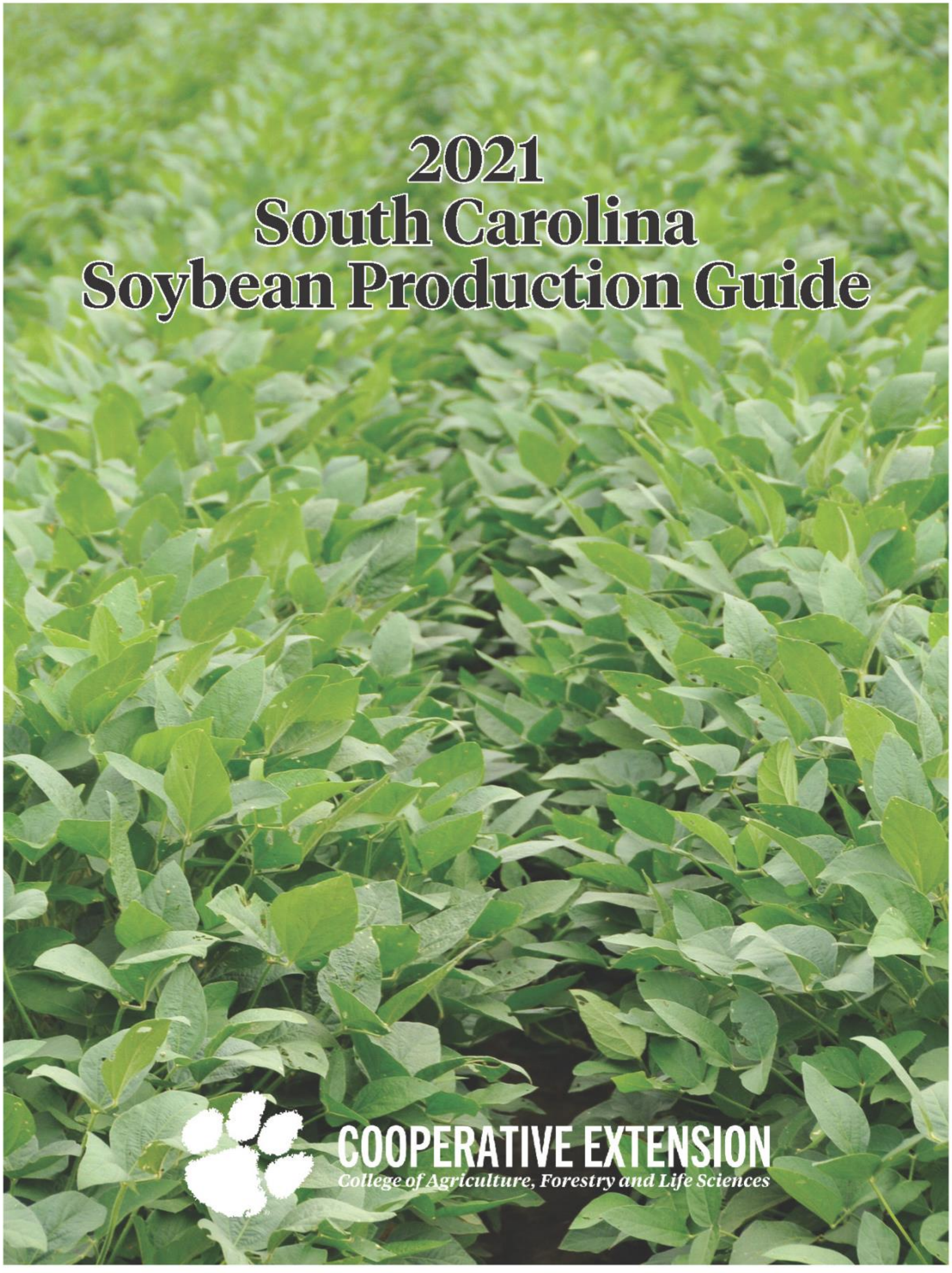
2021 South Carolina Soybean Production Guide



COOPERATIVE EXTENSION
College of Agriculture, Forestry and Life Sciences

2021 South Carolina Soybean Production Guide

Published by Clemson Cooperative Extension Service

www.clemson.edu/extension

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The 2021 South Carolina Soybean Production Guide is available as a PDF download at this link and can also be linked to from the the Agronomic Crops Program Soybean Production website .

South Carolina
SOYBEAN BOARD

Dear South Carolina Soybean Producers,

The South Carolina Soybean Board (SCSB) continues to be hard at work on behalf of all South Carolina soybean farmers. The SCSB works to ensure that farmers across the state are receiving the most current information on key topics that are likely to impact your operations.

As a result of your checkoff dollars, the SCSB invests approximately $100,000 annually in production-focused research. Your funds also allow the story of the soy industry to continue being told through our educational and promotional efforts. Soybeans remain a top cash crop in our state with a production value of over $125 million annually, according to the 2017 Census of Agriculture. Through the SCSB's efforts, we aim to keep soy growing in the Palmetto State while benefitting the bottom line of you, the producer.

The South Carolina Soybean Board (SCSB) is a farmer-run organization comprised of 12 farmer-leaders from throughout the state. The checkoff is collected when soybeans are sold. One-half of one percent of the price of each bushel is remitted into the checkoff. These funds are used for research, promotion, and education as it pertains to soybeans and the soy industry. Want to know more about the SCSB? Visit scsoybeans.org! Information on checkoff-funded research can be found on the website (scsoybeans.org/checkoff-at-work/funded-programs/).

Sincerely,

Dean Hutto

Dean Hutto

Farmer, Orangeburg County
Chairman, SC Soybean Board

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Introduction

Michael Plumblee, PhD

Soybean is one of the major row crops in the United States. According to the USDA National Agricultural Statistics Service, the acreage of planted soybeans increased in the United States from about 64.2 million acres in 1996 to 83.0 million acres in 2020. Soybean production has also increased from 2.38 to 4.14 billion bushels from 1996 to 2020 in the United States. In South Carolina, the acreage of planted soybean ranged from approximately 560 thousand acres in 1996 to 310 thousand acres in 2020. Table 1 shows the South Carolina soybean production by county in 2020.

Table 1. 2020 county soybean production in South Carolina. Bolded values represent top counties.

County	Planted (acres)	Harvested (acres)	Yield (bu/acre)	Production (bushels)
Aiken	N/A	N/A	N/A	N/A
Allendale	7,700	7,470	32.4	242,000
Anderson	3,100	2,980	37.9	113,000
Bamberg	4,300	4,020	35.3	142,000
Barnwell	3,400	3,250	39.7	129,000
Berkeley	N/A	N/A	N/A	N/A
Calhoun	N/A	N/A	N/A	N/A
Chesterfield	N/A	N/A	N/A	N/A
Clarendon	19,900	19,400	37.7	**731,000**
Colleton	2,300	2,110	28.9	61,000
Darlington	19,000	18,500	32.9	609,000
Dillon	**23,000**	**22,600**	**40.3**	**911,000**
Dorchester	5,000	4,550	36.7	167,000
Edgefield	N/A	N/A	N/A	N/A
Florence	**24,400**	**23,600**	30.9	**729,000**
Hampton	2,400	2,250	**40.0**	90,000
Horry	**37,000**	**36,100**	39.9	**1,081,000**
Kershaw	900	870	**47.0**	40,900
Lee	14,300	13,800	**42.9**	592,000
Lexington	2,600	2,280	37.5	85,500
Marion	11,500	11,100	33.7	374,000
Marlboro	18,900	18,400	34.1	627,000
Newberry	3,700	3,550	**42.8**	152,000
Oconee	1,100	1,060	**42.5**	45,100
Orangeburg	17,700	17,300	37.3	645,000
Pickens	200	200	34.0	6,800
Richland	2,300	2,210	**40.0**	88,400
Sumter	19,300	18,900	38.5	**728,000**
Williamsburg	27,400	26,400	30.7	**810,000**
All Other	38,600	37,100	35.0	1,300,300
State Total	**310,000**	**300,000**	**35.0**	**10,500,000**

Counties with the highest estimated soybean acreage (>20,000 acres) in 2020 were Horry, Williamsburg, Florence, and Dillon counties. These top counties accounted for about 36% of total planted soybeans in the State in 2020. The highest estimated soybean yields in 2020 were for Kershaw, Lee, Newberry, Oconee, Dillon, Richland, and Hampton Counties and ranged from 40 to 47 bushels/acre. The updated state average yield was 35 bushels/acre in 2020.

Marketing Soybean Production

Nathan Smith, PhD, and Scott Mickey

Profitable soybean production is critical for the sustainability of the farm business. Profitable production requires the producer to market their production at a price that covers the cost of production as well debt repayment, family living, and income tax needs, and equity growth. Soybean prices are influenced by both the supply of soybeans in the US and globally and the demand for soybeans by end-users. Successfully marketing soybeans requires several steps:

Step 1. Calculate price target that covers the cost of production and provides the earning needed for

- Family living and income taxes,
- Interest expense on operating and term debt,
- Equity growth.

Step 2. Identify pricing opportunities

- Compare market price against the breakeven price
- Evaluate fundamental supply and demand trends
- Review technical trends of the market

Step 3. Execute the sale

- Consider seasonality of soybean prices
- Choose the appropriate marketing tool - cash sale, futures, or options.
- Determine quantity to market

Let's see how these steps work using information made available in March 2021.

Step 1. Calculate price target

This producer expects 2021 soybean yield of 40 bushels and operating costs of $335 per acre this year. This is about $100 less than the Clemson enterprise budget for full season, non-irrigated strip-tilled soybeans but reflects the producer's management practices, tillage operations, labor efficiency, and soil type. Family living draws and debt service are expected to be $46 and $104 per acre, respectively. The producer also expects to receive $57 an acre for non-crop revenue such as government payments, refunds, and custom work. His break-even soybean price calculation is shown below (table 1).

Table 1. Break-even soybean price calculation per acre.

Calculation	Per Acre
Operating Cost	$335
Family Living	$46
Principal & Interest	$104
Total Cash Need	$485
Less: Non-Crop Revenue	-$57
Crop Revenue Required	$428
Expected Yield	$40
Break-Even Price	$10.70
Less: Harvest Basis	$0.10
Break-Even Futures Price	$10.60

Remember that every producer's breakeven price will differ according to their actual cost of production, family living needs, and debt repayment terms.

Step 2. Identify pricing opportunities

On March 26, 2021, November, soybean futures closed at $12.07 per bushel. This producer needs a futures price of $10.60 per bushel to pay operating expenses and expected family living and debt service needs. The price opportunity would provide $1.47 per bushel of equity growth or $59 an acre if the 40-bushel yield is achieved. It appears that a good pricing opportunity is available based on the current price and the producer's breakeven price.

Table 2 is a recap of USDA's World Agriculture Supply and Demand Estimates (WASDE) released in March 2021. The 21/22 column is estimated numbers for the soybean crop to be planted in 2021.

Table 2. Soybean Supply and Demand. USDA's WASDE 03/09/2021.

	19/20	**20/21**	**21/22**	**22/23**	**23/24**
	WASDE-610	WASDE-610	Estimate	Estimate	Estimate
Planted	76.1	83.1	90.0	89.5	89.0
Harvested	74.9	82.3	88.9	88.4	87.9
Yield	47.4	50.2	50.8	51.6	52.2
Beg Stocks	**909**	**525**	**120**	**137**	**185**
Production	3,553	4,135	4,517	4,562	4,590
Imports	15	35	35	15	15
Total Supply	**4,477**	**4,695**	**4,671**	**4,715**	**4,789**
Crush	2,165	2,200	2,210	2,195	2,220
Seed/Residual	105	125	124	125	135
Exports	1,682	2,250	2,200	2,210	2,225
Total Demand	**3,952**	**4,575**	**4,534**	**4,530**	**4,580**
End Stocks (ES)	**525**	**120**	**137**	**185**	**209**
Percent Use	13%	3%	3%	4%	5%
USDA Price	**$8.57**	**$11.15**	**$11.25**	**-**	**-**
Futures as of 03/26/21	**-**	**$14.38**	**$12.54**	**$11.35**	**-**

The first row to check on the WASDE report is the Ending Stocks row. The ending stocks in 19/20 were 525 million bushels and equal to 13% of the total soybeans used in the 2019-2020 marketing year. Ending stocks dropped to 120 million bushels in 20/21 and were projected to only be 3% of use. Note that when ending stocks decline, prices rise. The expected ending stocks for the 21/22 marketing year are about the same, so fundamentally, prices for the 2021 crop should be like the 2020 soybean prices. USDA forecast the average price for 21-22 soybeans at $11.25, much less than the futures price on March 26th of $12.07. This indicates another pricing opportunity!

Figure 1 shows the November soybean futures price activity from December 1, 2020, through March 26, 2021. The soybean market high was $12.54 on March 8, 2021. Since then, the price has dropped to its current level. However, the price was only $10.37 on December 1, 2020. The current down trend in soybean prices also indicates that this may be a pricing opportunity. These three factors indicate that a pricing opportunity exists for this producer.

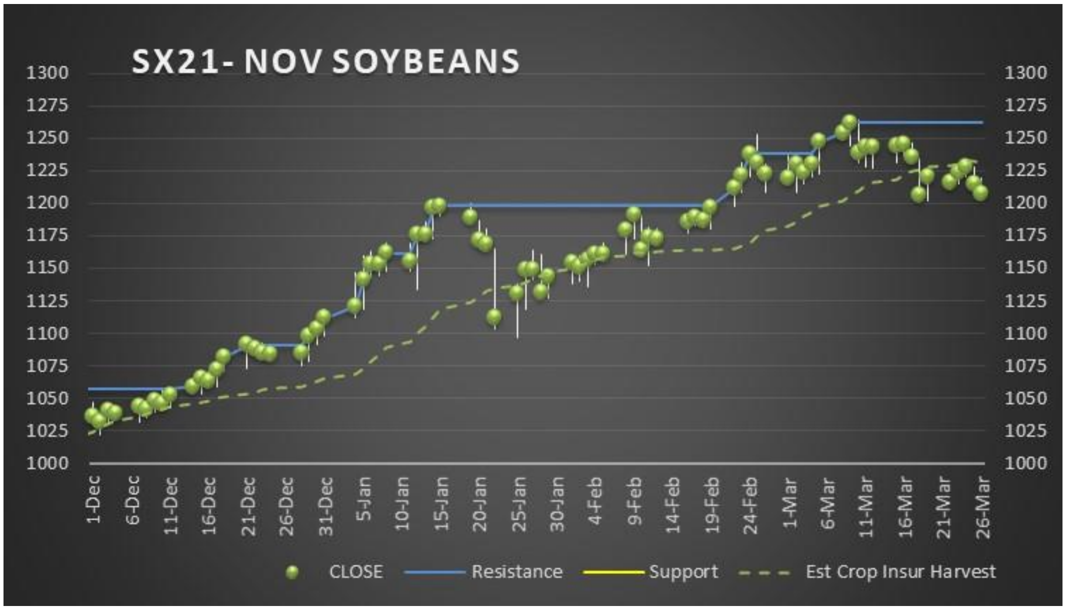


Figure 1. November soybean futures price activity from December 1, 2020, through March 26, 2021.

Step 3. Execute the sale

Commodity prices tend to follow a seasonal pattern of relatively higher prices around planting and lower prices at harvest. The seasonality of soybeans shows that historically soybean prices are highest in May and June and lowest in November. Unfortunately, this pattern is not perfect, as we found out in 2020. Nevertheless, this producer should consider pricing a portion of expected production soon while the price is profitable.

The method of pricing could be a cash forward contract which will require the producer to deliver the contracted quantity as outlined in the forward contract. Producers should use cash-forward contracts when they are comfortable with the delivery requirements. Alternatively, the producer could hedge their soybeans using the futures market. Futures contracts do not require delivery but will require the use of commodities broker. Producers will need to provide margin money to secure the trade and wire additional margin if prices rise. Put options allow producers to set a minimum price for soybeans in exchange for the option premium. The premiums are paid at the time of purchase and, like futures, require the use of a commodity broker.

Determining the quantity to market is one of the last decisions a producer needs to make. When using cash forward contracts, the minimum quantity is often 1,000 bushels. Futures and options contracts are typically in 5,000-bushel increments, although mini contracts of 1,000 bushels may be available. Given a 40-bushel expected yield, a 5,000-bushel contract commits 125 acres of soybeans. If growing 500 acres, one contract represents 25% of expected production.

Consider pricing up to your crop insurance guarantee before harvest. For example, if the producer has a 75% Revenue Protection policy, he may choose to price up to 30 bushels per acre before harvest. For this example, the producer may consider pricing 25% of production before planting (January to April), another 25% post-planting (May-August), and another 25% as actual production becomes clearer (September-October).

Marketing is important for the profitability of soybeans. Spend some time each week monitoring your marketing activity. If you would like more information about commodity marketing, read the weekly Commodity Market Outlook newsletter on the Clemson Extension Agribusiness Program Team website (clemson.edu/extension/agribusiness/marketing/commoditymarketing.html).

Soybean Vegetative and Generative Growth Stages

Michael Plumblee, PhD

Identifying the soybean growth stages is essential for proper crop management of pests, irrigation andfertility. Generally, soybean growth and development can be divided into vegetative (V) and reproductive (R) growth stages. The beginning of each stage starts when at least 50% plants in the field or area are at that stage. Vegetative growth stages start with the soybean emergence, and reproductive growth stages start with the first flower.

The growth stages are adapted from Fehr, W.R., C.E. Caviness, D.T. Burmood, and J.S. Pennington, 1971. Stage of development descriptions for soybeans, *Glycine max* (L.) Merr. Crop Science 11:929-931 and from 2004 edition of PM 1945 *Soybean Growth and Development* published by Iowa State University Extension, Ames, Iowa 50011.

Vegetative (V) Growth Stages

Vegetative growth stages in soybean (figure 1-4) begin with seedling emergence (VE stage) (table 1). Prior to germination, soybean seed absorbs water equal to approximately 50% of its weight. The elongation of hypocotyl brings the cotyledons out of the soil, which starts the soybean plant emergence process.

After emergence, unifoliolate leaves on the first node unroll in addition to cotyledons and start the VC stage. The following vegetative stages are designed numerically from V1, V2, V3, through V(n), based on the number of nodes with trifoliolate fully developed leaves unrolled. For example, the V1 stage starts with one unrolled, fully developed trifoliolate leaf on the second node. The (n) represents the number of the last fully developed trifoliolate leaf. A fully developed trifoliolate leaf is one that has unrolled or unfolded leaflets.

Table 1. Vegetative (V) soybean growth stages.

Stage	Description
VE	Plant emergence (depends on temperature and moisture).
VC	Unifoliolate leaves unrolled in addition to cotyledons. One node.
V1	One unrolled trifoliolate leaf. Two nodes
V2	Two unrolled trifoliolate leaves. Three nodes.
Vn	(n) number of trifoliolate unrolled; (n) + 1 number of nodes.

Figure 1. VE - Emergence.

Figure 2. VC - Unifoliolate leaves unrolled in addition to cotyledons.

Figure 3. V1 - One unrolled trifoliolate leaves.

Figure 4. V2 - Two unrolled trifoliolate leaves.

Reproductive (R) Growth Stages

The reproductive stages in soybean starts when at least one flower is present on the plant (table 2). These stages describe the development of flower (R1 and R2), pod (R3 and R4), seed (R5 and R6), and maturity (R7 and R8). Vegetative growth continues through some of the reproductive stages. The reproductive growth stages are described in the table 2 and shown in images below table 2.

Table 2. Reproductive (R) soybean growth stages.

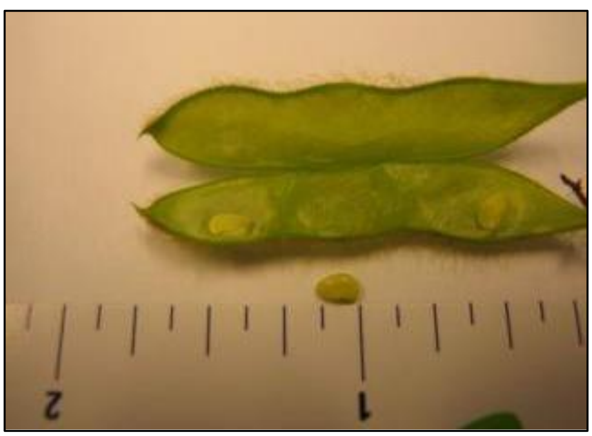
Stage	Description
R1	Beginning bloom. At least one flower is present on the main stem.
R2	Full bloom. Flowers are found on any of the top two nodes.
R3	Beginning pod. Pods are 3/16-inch long on one of the top four nodes.
R4	Full pod. Pods are 3/4-inch long on one of the top four nodes.
R5	Beginning seed. Seeds are 1/8-inch long on one of the top four nodes.
R6	Full seed. Pods are completely filled by seeds on one of the top four nodes.
R7	Beginning maturity. One mature pod found on the plant.
R8	Full maturity. 95% pods have reached mature pod color.

R1 - Beginning bloom. At least one flower on the main stem.

R2 - Full bloom. Flowers are found on any of the top two nodes.

R3 - Beginning pod. Pods are at 3/16-inch long on one of the top four nodes.

R4 - Full pod. Pods are at 3/4-inch long on one of the top four nodes.



R5 - Beginning seed. Seeds are at 1/8 inch long on one of the top four nodes.

R6 - Full seed. Pods are completely filled by seeds on one of the top four nodes.

R7 – Beginning maturity. One mature pod found on the plant.

R8 – Full maturity. 95% pods are matured.

Soybean Maturity Groups and Growth Habit

Michael Plumblee, PhD

Soybeans flower in response to day length and temperature and therefore are called facultative photoperiod sensitive. Varieties grown in the United States are divided into 13 maturity groups (MG), with MG 000 being the earliest and adapted to northern Minnesota and southern Canada, to MG X adapted to southern Texas. The earlier varieties bloom when days are long and nights are short, while the later-maturing varieties bloom under relatively shorter days and longer nights. During the summer, days are longer at more northern latitudes, therefore the early MG will initiate flowering when days are longer. Earlier and later maturing groups develop differently and knowing the growth habit of different maturity groups (MG) can help with the crop management.

Most indeterminate varieties are adapted to maturity group IV and earlier. These varieties have overlapping vegetative and reproductive growth stages. Terminal growth bud on the main stem continues to grow after the first bloom and most of the pods are on the main stem. Flowers and pods develop at different times and rates depending on node locations. Nodes with the earliest flowers located near the bottom of stem; therefore, an indeterminate plant may contain pods with developing seed at lower nodes while upper nodes contain only small pods or flowers.

Most varieties with a determinate growth habit (maturity group V and later) have distinct vegetative and reproductive growth stages. Number of nodes and plant height of the main stem are terminated at the full bloom stage (R2). However, branch growth continues after first bloom and the number of pods often greater on branches than the main stem.

Due to different blooming periods, the recommended planting dates of different maturity groups in South Carolina are:

- MG IV and earlier - April 15 through May 10
- MG V to VI - May 1 through June 10
- MG VII to MG VIII - June 1 through July 1

The following are approximate harvest dates of maturity groups V to VIII when planted full- season May 1 to June 10 in South Carolina:

- Group V: October 1 to 15
- Group VI: October 10 to 25
- Group VII and VIII: October 25 to November 15

Harvest maturity is an important consideration for farmers who wish to:

- Plant small grain for grazing early in the fall after soybean harvest
- Harvest soybeans from Carolina bays or river bottoms before late fall rains saturate soils and make harvest difficult and untimely
- Avoid early frost damage to the crop, especially in the Piedmont region
- Spread maturities to reduce risk of drought damage

Since there is a range of harvest maturities of about 45 days for MG V through VIII, there is also a range of time for the bloom through pod-fill stages. Because adequate soil moisture from bloom through pod fill is important for good yields, farmers should consider planting varieties from more than one maturity group to reduce the risks of drought damage during pod fill. For example, in 2001, a drought in South Carolina in August and September reduced yields of many late planted MG VII and VIII varieties. Farmers with earlier planted MG V and VI varieties were able to avoid most of the drought effects. The practice of spreading the maturity groups also spreads out harvest and thus helps to avoid harvest delays, which can reduce both yield and quality of the crop.

Planting Considerations

Michael Plumblee, PhD

Producing soybean offers farmers more flexibility in management and risk control options. For example, soybeans fit into several rotation systems with benefits to all involved crops. Also, soybean can be planted from late spring, as a full-season crop, through mid-summer or double-cropped after harvest of a winter annual crop such as wheat, rye, barley, oats, triticale, or canola. The following are suggestions for successfully planting soybeans to achieve stands for top yields.

Field Selection

Soybeans can be produced successfully on a wide range of soils. However, soils that are inherently fertile, well-drained, and possess good water-holding capacity will produce the highest yields. Based on the current cost of producing soybeans (see chapter one Production and Management Risks), fields should be selected with soils that have a productive potential (under dryland conditions) of at least 40 bushels per acre. Information to assist with field selection is presented in the County Soil Survey, available from local USDA-NRCS offices. This publication contains aerial maps which show the soil types in each field in the county. Reference can then be made to detailed descriptions of the soils, including their productive potential for various adapted crops. In addition to soil survey maps, utilizing geo-referenced equipment (Veris 3100) that can map the spatial variability in soil type and depth of the subsoil within fields could be used.

Rotation

Rotating soybean with other crops like corn, wheat, cotton, or tobacco is an important practice for managing pests, using soil-applied nutrients efficiently, and sustaining soil productivity. Rotation can result in a reduction in production costs due to less chemical inputs for controlling pests like weeds, diseases, or nematodes. Soybean can also effectively utilize residual nutrients left in the soil. In addition to these positive benefits, rotations usually improve yields due to the improvement of various soil biotic and physical characteristics.

Tillage

The sandy light-textured soils of South Carolina's Coastal Plain are low in fertility and water holding capacity and tend to form natural compacted zones or hardpans that are restrictive to root growth and development. Two types of hardpans are evident in most of these soils: a tillage pan 6- to 8-inches deep, caused by excessive tillage; and a lighter-colored sandy layer about 8- to 15-inches deep and 1- to 4-inches thick (the E horizon). The E horizon is more compacted than either the topsoil or subsoil (B horizon) and is difficult, if not impossible, for roots to penetrate. On Coastal Plain soils, deep tillage implements (in-row or broadcast subsoilers) are often needed to break compaction zones enabling roots to grow into the subsoil to access residual soil moisture and leached nutrients (including nitrogen, sulfur, and potassium).

South Carolina research has shown that in-row subsoiling in wide rows (30 to 38 inches) ahead of planting can increase soybean yields in the Coastal Plain by 10% to 15% with even greater response during dry years. It is critical that these tillage practices are conducted during periods in which soils are not excessively moist. Deep tilling "wet" soils will fail to destroy the restrictive layer and will create compacted areas along the sidewalls of the tillage shanks (see Figure 1). Note: For more information on tillage, please see the Double cropping Wheat and Soybeans with Conservation Tillage chapter.

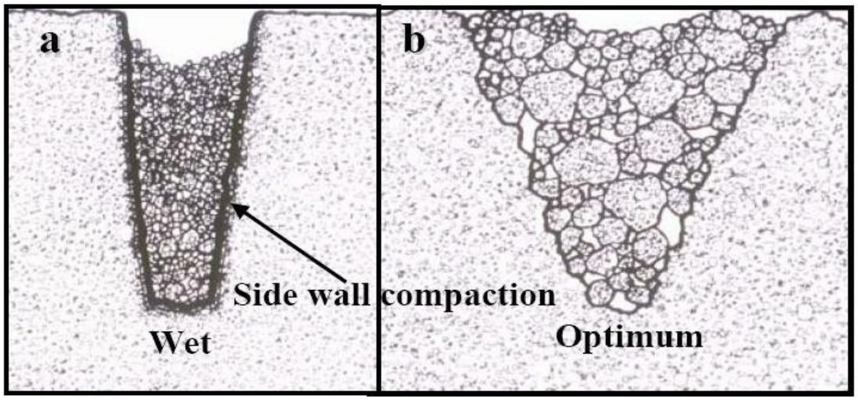


Figure 1. Subsurface view of tillage under "wet" and optimum moisture conditions. Note the side wall compaction that occurs when soil is too wet.

Tillage Depth

For achieving maximum economic returns from deep tillage, it is important to know the average depth to the subsoil and the depth and thickness of the restrictive layer. Research in the 1980s at the Clemson University Edisto Research and Education Center on three different soils showed that row subsoiling should be done 1 to 2 inches into the subsoil, so that roots can optimally access moisture and nutrients (table 1). Note: There is likely no benefit of tillage at depths greater than 2 inches below the upper surface of the subsoil.

Table 1. Soybean yields as influenced by depth to subsoil and depth of in-row subsoiling at the Edisto REC in Blackville, SC, 1984.*

In-row subsoiling depth (inches)	Depth to subsoil (inches)		
	8	12	16
	Bu/acre		
No subsoiling (disk only)	29	28	21
12	33	39	33
14	35	41	39
18	36	42	42

*Research by Tom Garner and Harold Musen.

Seedbed Preparation

Conventional seedbed preparation increases the costs of producing soybean and has several associated risks. While seedbed preparation using a disk harrow is practiced by many farmers, it is a practice that has many costs. Disking soil prior to planting stimulates weed emergence, compacts the soil at the 6- to 8-inch depth, causes rapid moisture loss from the soil surface, and increases wind and water erosion of the upper most layer of soil.

Seedbeds are most often prepared using conventional tillage when:

- Lime and/or fertilizer is to be incorporated into the plow layer
- Residual herbicide(s) must be incorporated
- Dense layer of weedy and/or crop residue exists on the soil surface
- A well-aerated seedbed is desired for optimum seed germination and emergence.

Note: All but soil-incorporated residual herbicides can be overcome.

Seedbed preparation for strip-tilled soybean involves a coulter and a narrow furrow opener (e.g., double disk). The coulter cuts through the surface residue (e.g., small grain residue if double- cropping), and the furrow opener prepares a narrow seedbed about an inch wide. Care must be taken to ensure the seed has good soil contact so that optimum germination/emergence can occur. Stand problems with conservation tillage can seriously cripple chances for good yields.

Soil Moisture

Having enough soil moisture present at planting is extremely important for good soybean stands. The soybean seed must imbibe 50 percent of its weight in water before germination can begin. This is why soybean seeds swell within an hour or so after planting if soil moisture is present. However, there can be enough moisture for "swelling" and not enough to complete the germination process, especially under extremely hot soil conditions. Seed in this situation are often attacked by bacteria or fungi and rot in the soil. Seed planted in soils too hot or dry can present other problems. Farmers who "dust in" their soybean crop and wait for a rain often have to replant because the seed baked, much like being in an oven. If soil moisture is limited, or if soil temperatures 1 to 1½ inches deep are over 100 degrees, the farmer should not plant until soil conditions are more favorable.

No-Till Planting

No-till planting is widely practiced for soybeans following wheat. Planting directly into wheat residue reduces soil temperatures, conserves soil moisture, and reduces soil erosion. However, obtaining a good stand can be challenging. During soybean planting, the seed furrow must be kept clean from the wheat straw. Otherwise, we may expect a reduced stand due to poor seed-soil contact. Wheat should be cut high to allow better herbicide penetration. The research conducted at Clemson University has shown that fertilization and deep tillage prior to planting wheat in the fall is usually sufficient for soybean planting in the summer.

Some other recommendations regarding planting soybeans in the no-till include increase of seeding rate by 10 to 15 percent and use planters with cutting coulters, double disk openers, and packer wheels to increase seed-soil connection and, therefore, soybean stand.

Soil Sampling and Fertility Management

Bhupinder S. Farmaha, PhD

The information provided in this chapter is to help growers make decisions related to soybean fertility programs to optimize yields, conserve natural resources, and increase farm profits. For complete detail, readers are referred to Clemson University Extension Circular EC 476, Nutrient Management for South Carolina (https://www.clemson.edu/extension/camm/manuals/publications/nutrient_management_for_south_carolina_ec476e.pdf). To achieve high soybean yields in South Carolina, it important to select fertile, well-drained soils and address production issues such as sub-soil compaction, low pH, and nutrient deficiencies, etc. The most popular and quick way to alleviate soil compaction is to break the sub-soil hardpan using in-row subsoiling or deep tillage implements at the time of planting. Soil tests help to determine the soil pH and nutrient levels, and thus any need for lime and/or fertilizer applications. These tests can be performed at the Clemson University Agricultural Services Lab to a private lab, which provides soil analyses and nutrient recommendations on a fee basis. Local County Extension office can help with soil sample bags and submissions forms and give advice on taking soil samples

Soil Testing

The first step in soil testing is to obtain a representative soil sample from each section of the field. The different sections could be due to different soil and landscape characteristics, cropping history, or known yield variations within the field. Different soil samples from each section of the field can help to determine if lime and fertilizers should be supplied uniformly across the field or differently between sampled sections.

The following are steps for obtaining a representative soil sample:

- Divide field into 2.5-acre areas (also used in the precision ag sampling) based on similar management history and soil characteristics (sample should not represent a field over 10 acres).
- Take into consideration difference in surface color is the most evident feature separating soil types, indicating possible variability in texture, organic matter content, and drainage.
- Nutrient removal rates by crops are important in determining residual soil fertility levels.
- Therefore, cropping history is another important factor to consider when defining a sample area.
- Construct an accurate map of the field to take samples from the same areas each year, preferably in the fall after harvest, to enhance the relevance of annual comparisons.

Taking soil samples:

- Obtain 10 to 20 soil cores (brush away surface plant residue material) from a 6 to 8-inch depth for tilled and 3 to 4-inch for no-till areas in a zigzag pattern throughout the area to ensure good representation.
- Place soil cores in a clean plastic bucket and mix thoroughly.
- Fill a one-pint sample box with the soil subsample.

It is strongly recommended to conduct soil sampling every year and send the samples to lab for analysis whether or not lime or any fertilizers are needed for soybean production. Detailed information about precision soil sampling techniques can be found in *Precision Agriculture-Based Soil Sampling Strategies* (Farmaha, 2020).

Clemson University lab's standard soil test report consist of a test for soil pH (active acidity), buffer pH (to estimate total exchangeable acidity), phosphorus, potassium, secondary nutrients (calcium and magnesium), and micronutrients (zinc, manganese, copper, boron, and sodium).

Soil pH and Liming

Optimum soil pH for soybean production is between 6.0 and 6.5 for most soils in South Carolina. Soil pH, either too low or too high, can be detrimental to soybean growth. If soil tests show a low pH, lime can be applied to enhance yield potential by reducing the toxicity of soil aluminum and/or manganese, improving the availability of phosphorus and potassium, and increasing the supply of calcium and magnesium (with dolomitic lime) (Figure 1). High pH conditions in most South Carolina soils are a result of over-liming and are costly and difficult to remedy. However, following the lime recommendation from a representative soil sample should be sufficient to avoid excessively high pH situations.

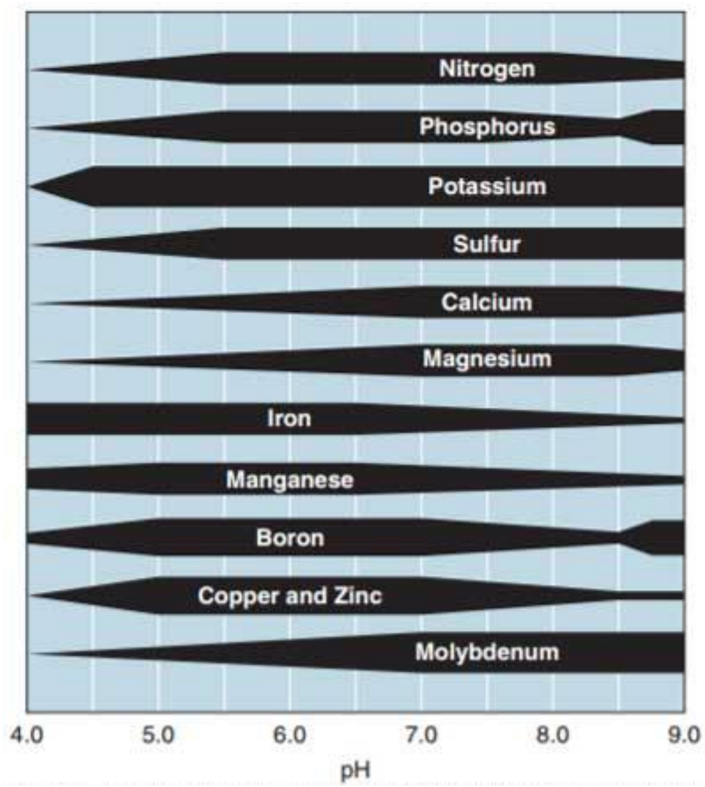


Figure 1. Impact of soil pH on nutrient availability (University of Illinois Agronomy Handbook).

Soil pH and the buffer pH value are needed to make a reliable lime rate recommendation. The amount of lime required can vary based on cropping history, organic matter, soil texture, soil pH, parent material, and manure applications. Lime should be applied as many weeks prior to planting as possible. Thorough mixing of the lime into the plow layer maximizes its rate of reaction and distribution in the root zone. Using dolomitic limestone to maintain soil pH in the recommended range will provide adequate levels of calcium and magnesium for optimum crop growth. Using calcitic limestone when soil magnesium is low will likely result in magnesium deficiency of the crop; however, calcitic limestone can be used to increase soil pH when soil magnesium is adequate. If magnesium levels are adequate in soils, then supplying extra magnesium with dolomitic limestone should not hinder the uptake of other required nutrients from the soil. Therefore, the selection of dolomitic limestone versus calcitic limestone should be based on cost involved and availability at the time of application. Further information about selecting a lime source can be found in *Basis of Selecting a Lime Material* (Farmaha, 2019).

It is advisable to incorporate lime prior to establishment of no-till cropping because surface-applied lime is slow to increase soil pH. Once no-till is established, frequent low rate lime applications will be more effective than infrequent high rate applications at maintaining proper pH throughout the rootzone. Soil sampling in two depth increments (0-3” and 3-6” for instance) rather than the traditional single depth (0-6”) may be warranted to track stratified pH changes.

Nutrient Recommendations

Nutrient levels on the soil test report are indexed into the following categories:

Low: Soil plant nutrient element level is deficient, and an application of this element will result in a significant yield increase.

Medium: Soil plant nutrient element level is adequate for moderate agronomic crop yields, but a yield response can be expected about 50% of the time from an application of this element

Sufficient: Soil plant nutrient element level is in that range adequate to meet the crop requirement as well as that needed for consistent high crop yield production. A maintenance application rate can be given to compensate for expected crop removal.

High: This soil-plant nutrient element level can adversely affect crop yield and product quality, and a further increase can lead to crop yield decreases as well as plant nutrient element imbalances. Therefore, no addition of this element is recommended.

Excessive: This soil-plant nutrient element level will adversely affect plant yield, create nutrient element deficiencies due to imbalances, and can lead to potential ecological damage to the surrounding environment.

Sulfur, manganese, phosphorus, and potassium recommendations for soybean production are made based on yield goals and nutrient levels in the soil. Fertilizer recommendations are made based on several years of soil test calibration research conducted in South Carolina and neighboring states. The complete information for fertilizer recommendation for soybean production in South Carolina can be found at https://www.clemson.edu/public/regulatory/ag-srvc-lab/soil-testing/pdf/agronomic_crops.pdf.

Table 1. Phosphorus and potassium fertilizer recommendations for soybean-based on yield goal and soil test levels in South Carolina.

Phosphorus	Potassium				
	Low	Medium	Sufficient	High	Excessive
	-----------------*pounds of P2O5-K2O per acre for yield goal of 30 bu/ac*-----------------				
Low	90-80	90-60	90-40	90-0	90-0
Medium	60-80	60-60	60-40	60-0	60-0
Sufficient	30-80	30-60	30-40	30-0	30-0
High or Excessive	0-80	0-60	0-40	0-0	0-0
	-----------------*pounds of P2O5-K2O per acre for yield goal of 40 bu/ac*-----------------				
Low	95-90	95-70	95-50	95-0	95-0
Medium	65-90	65-70	65-50	65-0	65-0
Sufficient	35-90	35-70	35-50	35-0	35-0
High	0-90	0-70	0-50	0-0	0-0
	-----------------*pounds of P2O5-K2O per acre for yield goal of 50 bu/ac*-----------------				
Low	100-100	100-80	100-60	100-0	100-0
Medium	70-100	70-80	70-60	70-0	70-0
Sufficient	40-100	40-80	40-60	40-0	40-0
High or Excessive	0-100	0-80	0-60	0-0	0-0
	-----------------*pounds of P2O5-K2O per acre for yield goal of 60 bu/ac*-----------------				
Low	105-110	105-90	105-70	105-0	105-0
Medium	75-110	75-90	75-70	75-0	75-0
Sufficient	45-110	45-90	45-70	45-0	45-0
High or Excessive	0-110	0-90	0-70	0-0	0-0
	-----------------*pounds of P2O5-K2O per acre for yield goal of 70 bu/ac*-----------------				
Low	110-120	110-100	110-80	110-60	110-0
Medium	80-120	80-100	80-80	80-60	80-0
Sufficient	50-120	50-100	50-80	50-60	50-0
High or Excessive	0-120	0-100	0-80	0-60	0-0
	-----------------*pounds of P2O5-K2O per acre for yield goal of 80 bu/ac*-----------------				
Low	115-130	115-110	115-90	115-60	115-0
Medium	85-130	85-110	85-90	85-60	85-0
Sufficient	55-130	55-110	55-90	55-60	55-0
High or Excessive	0-130	0-110	0-90	0-60	0-0

Phosphate and potash fertilizers, along with other micro-nutrients, should be applied at the recommend rate at the time of planting. Phosphate and potash fertilizers should be applied as a broadcast application or in a band of 2 inches below and 2 inches to the side of the soybean row. All recommended fertilizers for no-till soybeans should be broadcast prior to planting. Plant tissue testing should be used during the growing season to detect any nutrient deficiency and correct accordingly. Multi-nutrient fertilizers should also be applied based on the soil test recommendations. Boron applications in irrigated soybeans or at high soil pH should be based on leaf concentrations of boron. Soybean yield will respond positively to foliar-applied boron only when concentrations in leaves are ten ppm or less. In such instances when boron is needed, it should be applied at 0.2 lb/A at the early-pod stage (1/8 to 1/4-inch pods) and can be mixed with insecticides if needed; however, tank mixing boron or other foliar applied nutrients with Roundup may severely reduce weed control. Boron applied at 0.2 lb/A will cost about $2/acre plus application costs. Applications of boron to plants having boron concentrations greater than 60 ppm may result in yield decreases; therefore, routine use of boron is discouraged.

It is highly recommended to frequently do sub-soil testing when depth to the hardpan is no greater than 20 inches and disrupted by in-row subsoiling. The fertilizer application rates should be adjusted based on sub-soil nutrient reserves, especially for phosphorus and potassium.

It is recommended to apply inoculum on soybean seed when soybeans have not been planted within three years or when planted in sandy soils.

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Selecting the Right Varieties

Michael Plumblee, PhD

One of the most important decisions farmers make each year is variety selection. In order to maximize yield, selecting varieties with nematode and/or disease resistance and top-yielding varieties that match the soil, pest, herbicide program, and managerial (e.g., plant date) conditions imposed is essential. Selection is complicated by the large number of varieties commercially available (50+). New varieties and promising breeding lines are annually evaluated in official Clemson University tests. Test locations are at the Pee Dee Research and Education Center (REC) at Florence, Edisto REC at Blackville, and Piedmont REC at Pendleton. Grain yield, plant height, harvest maturity, and lodging are measured for each variety at certain locations. Researchers may also evaluate nematode or disease resistance at certain locations. Performance results are available both on the Internet and at County Extension offices. Farmers are encouraged to check the performance data when selecting varieties.

Variety Selection

The following steps should be referenced when selecting varieties:

- Select nematode-resistant varieties for fields where parasitic nematodes (soybean cyst, southern and peanut root-knot, Columbia lance, or reniform) have been identified as a problem.
- Choose varieties that are high-yielding over multiple years (environments) and locations.
- Consider varieties with good tolerance to diseases, lodging, and shattering.
- Select varieties appropriate for the time of planting [maturity group (MG) IV and earlier for April 15 through May 10, V to VI for May 1 through June 10, MG VII through MG VIII for June 1 through July 1].

If you have nematodes, the best variety may not yield well if it doesn't have resistance. There are some choices for root-knot and other non-cyst nematodes. Maturity group is very important as well, especially when spreading risk is important or a grower is farming over large distances or in double-crop settings.

Planting Dates and Populations

Michael Plumblee, PhD

In South Carolina, Group V and VI varieties offer top yield performance when full-season planting occurs from May 1 until June 10. Group VII and VIII varieties are recommended for later planting dates to allow adequate stem elongation prior to flowering. However, research has shown about a one-half bushel loss in yield potential for each day of planting delay after mid- June. For soybeans planted after June 10, seeding in row widths >30 inches is discouraged because the crop is not likely to lap the row middle and produce yields equivalent to drill-seeded soybean under a shortened growing season (see Figure 1).

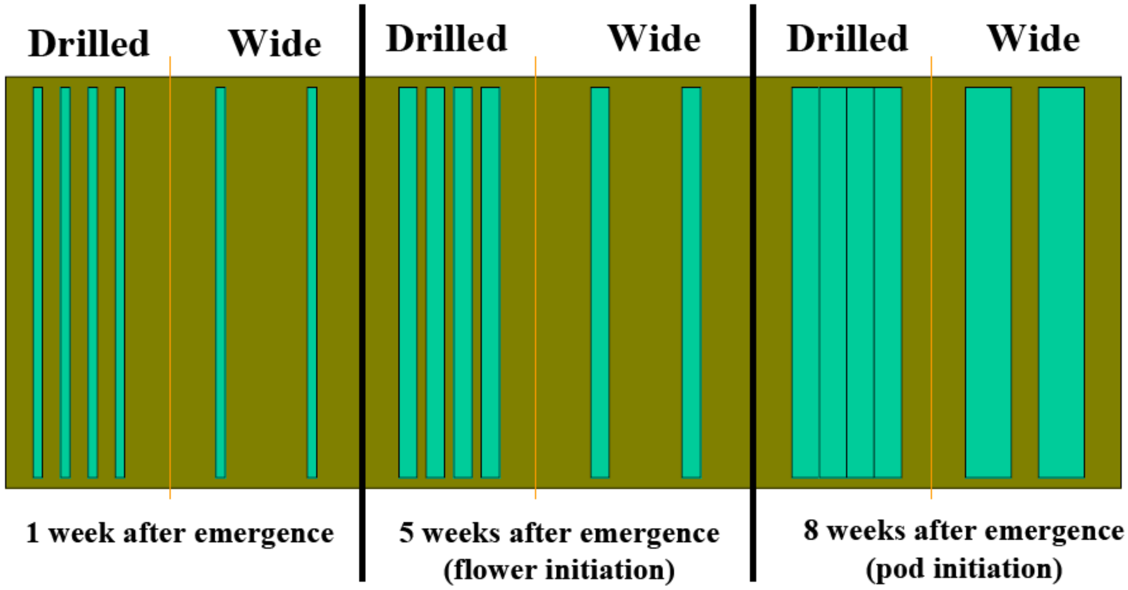


Figure 1. Schematic diagram of canopy development of 'late' planted drilled and wide row soybeans. Because canopy development ceases near pod initiation, wide-row soybean fails to harvest sunlight from the row-middles, thus limiting yield.

Drilled soybeans planted after June 10 in South Carolina have shown to consistently provide a 10- to 15-percent greater yield than soybeans planted in wide rows.

Farmers should use plants per row foot as a seeding rate guide rather than pounds per acre. Significant differences in seed size occur among varieties. Seeding rates based on pounds per acre can cause an inadequate or excessive population. In addition, it may lead to an added expense, especially when using herbicide resistant varieties in which a technology fee is accessed to each bag of seed purchased. For top yields, seeds should have a minimum germination of 80%. Table 1 shows the number of seeds per row and seeding rates for different row spacings. Under optimum soil moisture conditions, the current seeding rate recommendations for various row spacings are:

- 8 seeds per row foot for 38-inch rows
- 7 seeds per row foot for 30-inch rows
- 3 to 4 seeds per row foot for 15- to 20-inch rows
- 2 to 2.5 seeds per row foot for drilled rows less than 10 inches wide

For maturity group V through VII, research at the Edisto REC has found that drill-seeded soybean yields were similar when seeded at 150,000 seed/acre (2 seed per row foot) compared with 250,000 seed/acre (3.3 seed per row foot), which has been commonly used by many growers. The only time seeding rates should be increased is when planting with conservation tillage into dense residue that limits seed-soil contact, and seeding rates should only be increased by 15% in this instance.

Soybean seed should be planted at about ¾ to 1 inch deep in soil moisture adequate for both germination and emergence. Follow this rule of thumb for determining if moisture is ideal for planting: a handful of a typical sandy loam soil with optimum moisture for planting should "ball up" and then fall apart as you form and then release a tight fist.

Table 1. Number of seeds per row and seeding rates for different row spacings.

Seed #/row	Row spacing (inches)				
	7.5	20	30	36	38
	Seeding rate/acre				
1	69,696	26,136	17,424	14,520	13,756
1.5	104,544	39,204	26,136	21,780	20,634
2	139,392	52,272	34,848	29,040	27,512
2.5	174,240	65,340	43,560	36,300	34,389
3	209,088	78,408	52,272	43,560	41,267
4	278,784	104,544	69,696	58,080	55,023
5	348,480	130,680	87,120	72,600	68,779
6	418,176	156,816	104,544	87,120	82,535
7	487,872	182,952	121,968	101,640	96,291
8	557,568	209,088	139,392	116,160	110,046
9	627,264	235,224	156,816	130,680	123,802
10	696,960	261,360	174,240	145,200	137,558
11	766,656	287,496	191,664	159,720	151,314
12	836,352	313,632	209,088	174,240	165,069

Seed Inoculation

Michael Plumblee, PhD

The soybean plant is capable of supplying much of the nitrogen (N) for growth through N fixation. Living symbiotically (both organisms receive benefits) in the root nodules of the soybean plant, N-fixing bacteria, Bradyrhizobium japonicum, remove nitrogen from the air and provide it to the plant. If nitrate nitrogen is present in the soil, either from manure, sludge, or fertilizer, the bacteria do not fix nitrogen. The plant then preferentially uses the soil nitrogen until it is depleted, at which point the bacteria will again function to provide nitrogen to the plant.

Efficient strains of N-fixing bacteria are common in most South Carolina fields with a recent history of soybean production. Also, strains indigenous to our soils are extremely competitive with introduced strains when forming root nodules. For these reasons, it is very rare that soybeans will respond to seed-applied inoculants containing Bradyrhizobium japonicum.

It is important for farmers to maintain an optimum soil pH to ensure effective N-fixing activity. Low soil pH can sometimes cause a deficiency of molybdenum, a minor element critical for the N-fixing process. Molybdenum deficiency can be corrected by liming the soil to correct soil pH or by adding a seed treatment of sodium or ammonium molybdate at 2 to 4 oz/bu. To determine if applying an inoculant will be justified, consider the following “rule of thumb.” If the field in question has a recent (within three years) history of soybean production, an inoculant is not recommended (unless soybeans are planted on sandy soils).

The following precautions are suggested when using an inoculant:

- If molybdenum and/or a fungicide are used, add these products to the inoculated seed in the planter-box immediately before planting.

If an inoculant is needed, purchase fresh material (bacteria only) and keep in a cool place until used. Thoroughly mix with moistened seed.

Double Cropping Wheat and Soybeans with Conservation Tillage

Michael Plumblee, PhD

Double-cropping soybean after wheat is a popular practice in South Carolina, with an estimated one to two-thirds of the soybean crop planted in June after wheat harvest. Even though double cropping has been a profitable system for many farmers, high costs, time constraints, and labor have caused more interest in adopting conservation tillage for both crops.

Soil Characteristics

The sandy soils typical of the southeast Coastal Plains are inherently low in fertility and water holding capacity. They are also subject to leaching and often exhibit significant runoff during the growing season when most rainfall comes as thunderstorms. The organic matter content of the topsoil (A horizon) for these soils is low (usually less than 1 percent), and with excessive tillage this figure may be closer to 0.5 percent. This situation results in poor soil tilth and reductions in rainfall infiltration potential. Some agronomists attribute the lowering of soil productivity and crop yield potential to these factors. Also, excessively tilled low organic Coastal Plain soils possess less buffering potential against the effects of drought stress.

Another important characteristic of most Coastal Plain soils is a hardpan that restricts root growth and increases the potential for serious yield losses during drought. The hardpan, or E horizon, is usually 1 to 4 inches thick and about 7 to 15 inches deep and is lighter in texture than the topsoil or plow layer (A horizon). Subsoiling is the most common method farmers use to break the hardpan to encourage root growth into the clay or B horizon, where additional moisture and nutrients are available. Yield increases for wheat and soybean can be from 10 to 15 percent, or more, with good deep tillage practices for alleviating the effects of soil compaction. Chisel plow tines are spring loaded and thus are relatively ineffective in disrupting the E horizon.

Conservation Tillage Tools

Deep tillage tools that feature bent shanks or "wings" are available for use in conservation tillage systems. These plows (Tye or Bingham Bros. Paratill, Worksaver's Terra-Max, and DMI's Ecolo- Till), equipped with coulters for cutting through surface residues, lift the soil and then drop it as they are pulled through the field. This action shatters hardpans like dropping concrete. Such practice effectively loosens the soil above the shanks or wings. Thus, there is almost a broadcast type (about 70 percent of the soil is affected) of deep tillage vs. the furrow type of tillage effect with conventional shank subsoilers. The idea is that this type of hardpan shattering will last longer than the furrow-type done by conventional shanks. Experience has shown that reconsolidation of compacted zones occurs earlier with the conventional shank type of deep tillage. Also, crop roots can more effectively "search" the profile for water and nutrients after use of these winged plows.

One-Pass Wheat Planting System

Conventional wheat planting systems in the Coastal Plains typically involve a minimum of two or three diskings to bury previous crop residue, followed by subsoiling, smoothing, and then planting. For soybean, the small grain residue is typcically either burned or disked, or planted with a one- pass subsoil-planting operation. Energy consumption and the investment in equipment, time and labor is high. Also, little consideration is given to the potential for runoff and/or erosion with conventional tillage systems. A reduced tillage, one-pass wheat/soybean system has the potential to save energy, reduce production costs and erosion, provide food for quail and other wildlife, and expand the planting interval available to farmers.

Considerations

The bottom line in these discussions of reduced-tillage systems for profitable wheat/soybean double-cropping systems for South Carolina is as follows:

- Winged plows effectively break soil hardpans in a broadcast fashion and leave most of the surface residues undisturbed.

- Deep tillage tools like the subsoiler will continue to be used, as will wide 30- to 40-inch rows for soybeans; however, farmers who wish to adopt drilled or narrow row (<30 inch) conservation tillage technologies for double-cropping, as those discussed in this section, will quickly recognize the benefits in better yields, need for less labor and equipment, and enhanced environmental compatibility.
- Better planting equipment and herbicide resistant varietieswill help enhance the chances for success.

Soybean Irrigation

Michael Plumblee, PhD

Irrigated soybean acres are relatively low in South Carolina compared to other commodities such as corn, peanut, and cotton. However, irrigating soybean has the potential to maintain or improve yield if crop water use is met at the right time and with the right amount of water. The goal of supplemental irrigation is to make up for rainfall deficits to meet crop water use demand. Understanding how much water is used by a soybean crop at each crop growth stage is imperative in accurately and effectively scheduling irrigation (table 1).

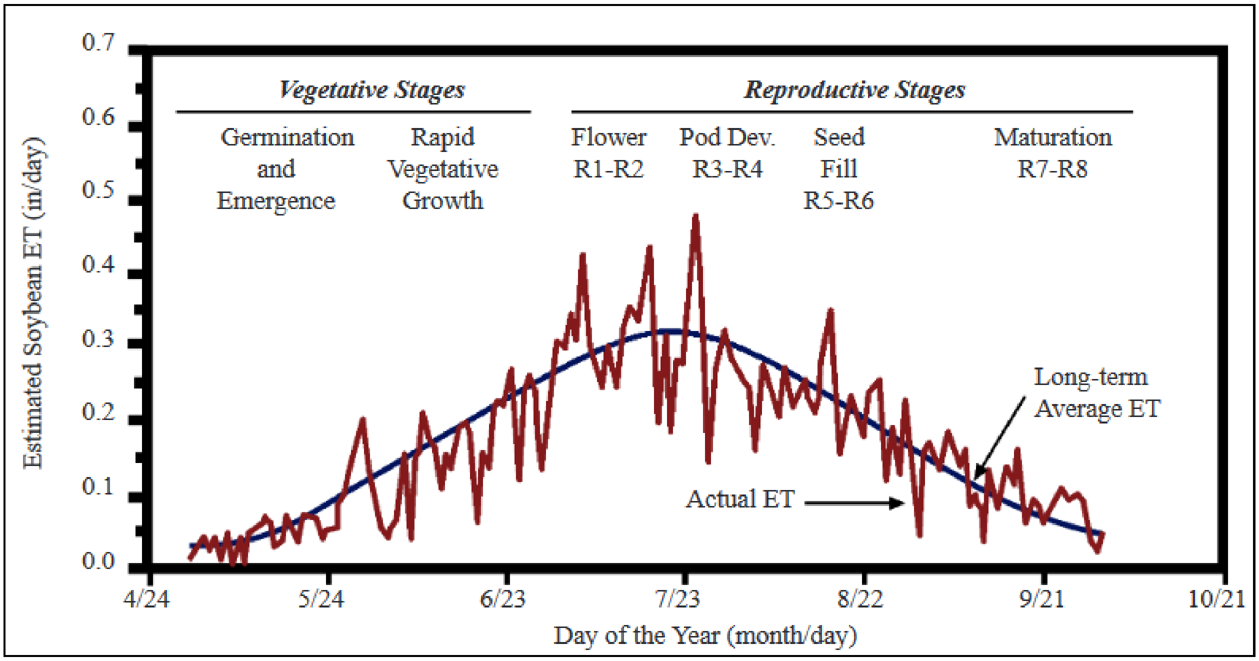
Irrigation in soybean can have several other secondary advantages such as improving the effectiveness of soil-applied herbicides, stand establishment in late-planted or double-cropped systems, and chemigation.

Irrigation Scheduling in Soybean

Table 1. The soybean seasonal crop water use and irrigation schedule.

Days after Planting	Weeks After Planting	Inches per Week	Inches per Day
1 to 7	1	0.16	0.02
8 to 14	2	0.53	0.08
15 to 21	3	0.65	0.09
22 to 28	4	0.74	0.11
29 to 35	5	0.89	0.13
36 to 42	6	1.08	0.15
43 to 49	7	1.18	0.17
50 to 56	8	1.28	0.18
57 to 63	9	1.33	0.19
64 to 70	10	1.43	0.20
71 to 77	11	1.45	0.21
78 to 84	12	1.51	0.22
85 to 91	13	1.46	0.21
92 to 98	14	1.41	0.20
99 to 105	15	1.36	0.19
106 to 112	16	1.22	0.17
113 to 119	17	0.82	0.12

Soybean water use curve by growth stage*



*This water use curve is to be used as a guide for scheduling irrigation and water use values may not directly correlate with calendar dates or growth stages.

Several better alternatives than the above rule-of-thumb method are available. The Irrigator Pro model (http://www.ars.usda.gov/services/software/download.htm?softwareid=204) bases irrigation decisions on soil moisture sensors. The UGA EASY (Evaporation-based Accumulator for Sprinkler-enhanced Yield) Pan Irrigation Scheduler allows crop water needs to be monitored in the field using a low-cost system that can be built on farm after a trip to the hardware store (http://extension.uga.edu/publications/detail.cfm?number=B1201).

Soil moisture sensors are another alternative to the checkbook type scheduling methods listed above. Some of the benefits from using an irrigation schedule to know when to irrigate are to meet the crop water demand with supplemental irrigation at appropriate timings throughout the growing season; Reduce the likelihood of plant stress, often times yield has been lost by the time visual stress symptoms are observed; Reduce over-watering crops; Maximize pod yield, quality, and profits. Benefits of scheduling irrigation with soil moisture sensors relative to other methods are that they allow real-time site-specific monitoring of soil moisture, they can assist with determining water sensitive periods throughout the growing season by accurately depicting crop water use, and sensors help quantify the actual amount of rainfall that enters the soil and into the rooting zone.

Soil moisture sensors are separated into main categories based on how they read soil moisture. The first category, volumetric sensors (Volumetric water content and Capacitance sensors) measure the amount of water in a given volume of soil providing a soil water content percentage. The second category, soil water tension (Gypsum blocks and Watermark sensors) measure the force that the plant roots must overcome to extract water from the surrounding soil particles. These sensors provide readings in units of kilopascals (kPa) or centibars (cbar). Several differences exist between the two categories of sensors including price, accuracy, recurring subscription costs and telemetry or how data is accessed; however, both categories are suitable for irrigation scheduling in row crops.

The following are recommendations on commonly asked questions with regard to soil moisture sensors:

How many sensors do I need? At least one sensor or set of sensors (if multiple sensors are needed for multiple depths) per irrigation management zone (i.e., under each center pivot) will aid in irrigation decision making. Other scenarios where more than one sensor per irrigation management zone may be warranted include changes in soil texture across the field in areas that can be managed separately or with the use of a variable rate irrigation system. Furthermore, if a particular system takes several days to make one revolution, consider placing sensors at the start and stop of the irrigation cycle to determine if the system needs to continue on to another irrigation cycle at completion of the prior cycle.

Where do I put my sensors within the field? Several factors should be considered when placing sensors in the field to ensure a representative reading will be obtained. Consider soil texture differences; try to manage irrigation based on the soil texture that represents the majority of the field. Avoid putting sensors in areas that are very droughty or hold water during the growing season. If yield data is available, yield maps can be used as another tool to evaluate areas of the field to avoid or try to stay in with placement. Try to place sensors in the field after planting and in areas where a representative stand exists. Avoid traffic rows and minimize damage to plants when installing sensors. Due to the limitations on irrigation sprinkler packages on center pivot systems avoid placing sensors near the center point of the system. It is recommended to try to install sensors a tower or two from the end of system to ensure irrigation uniformity.

Do I install sensors in the row or row middle? Install soil moisture sensors within the planted row of plants. By installing sensors within the row accurate measurements of soil moisture within the crops rooting zone can be achieved. With all soil moisture sensors sensor to soil contact is essential in order to accurately read soil moisture. Therefore, the correct installation of soil moisture sensors is critical to the sensors working correctly.

How do I know when to irrigate based on the soil moisture sensor? Most sensor manufacturers have generic threshold values associated with the crop and soil texture that the sensor is being placed into. Typically, these threshold values reflect allowing the plant available water of a specific soil texture to deplete 25 to 50% before irrigation is applied to recharge. On-going research at Clemson University is evaluating sensor thresholds in multiple crops to develop sensor threshold recommendations based on South Carolina soil textures and crop.

If soil water tension, Watermark, type soil moisture sensors are being utilized to schedule irrigation, Clemson University has put together a simple web-based application that can be accessed via smartphone or computer to take actual sensor readings and assist with making irrigation decisions based on predefined or manually entered thresholds. The web-based app can be found online at: www.precisionag.sites.clemson.edu/calculators/irrigation/watermarkcalculator or through a Clemson Precision Agriculture website (www.irrometer.com/thresh.html).

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Weed Management in Soybean

Michael W. Marshall, PhD

Successful and profitable soybean production relies on managing pests. Of the pests in soybean, weeds rank as the most deleterious toward crop yield. The presence of weeds during crop growth and development leads to yield and quality reduction, depending on the weed species. In addition, weeds can be an impediment for harvest machinery. Weeds compete for water, light, nutrients, and space. For example, one Palmer amaranth plant per 3-ft of soybean row can reduce yield up to 25 percent. Therefore, it is very important to prevent and/or control existing weeds before competition occurs and reduces crop yield. The following are the most troublesome weeds in South Carolina soybean production (table 1).

Table 1. Troublesome weeds in South Carolina soybean.

Weed	Lifecycle
Palmer amaranth	Annual
Sicklepod	Annual
Annual morningglory	Annual
Texas panicum	Annual
Broadleaf signalgrass	Annual
Crabgrass	Annual
Yellow nutsedge	Perennial

Weeds can be grouped by lifecycle: annuals, biennials, and perennials. Annuals complete their lifecycle within one year or growing season. Temporally, there are two types of annuals: warm-season and cool-season. Palmer amaranth and large crabgrass are examples of warm-season annuals. Annual bluegrass and henbit are examples of cool-season annuals. Since annuals rely entirely on seed production for survival, eliminating or minimizing seed production is the most effective strategy for reducing population numbers over time. Seed size and production varies with annual weeds. Small-seeded annual weeds, such as Palmer amaranth, can produce up to 500,000 seeds per plant in a single growing season. Large seeded annual weeds tend to produce fewer seed (e.g., cocklebur) per plant.

Biennials are plants that need two years to complete their lifecycle. Bull thistle is an example of a biennial weed. During the first season, the plant forms a rosette (a whorl of leaves at the soil surface on top of a taproot) that overwinters and the following spring/early summer, it bolts (forms a stalk) on which flowers, fruits, and seed are produced. Management of biennial weeds is recommended during the rosette or vegetative growth stage during the first year of the lifecycle.

Weeds that have lifecycles longer than two years are perennials. Perennials can reproduce by seed and/or vegetative structures. Johnsongrass is an example of a perennial weed that reproduces by seed and underground stems (e.g., rhizomes). Perennial weeds can be classified into two groups: simple and spreading. A simple perennial produces new shoots each year from reproductive buds located on the crown of a taproot. Common pokeweed is an example of a simple perennial. In contrast, spreading perennials often form colonies using aboveground stems (e.g., stolons), underground stems (i.e., rhizomes), and/or creeping roots which produce new daughter plants from the source plant. Horsenettle is a broadleaf perennial weed that reproduces via creeping roots which gives rise to new daughter plants. Other perennial reproductive structures include tubers (e.g., yellow nutsedge) and bulbs (e.g., wild garlic). Perennials are the most difficult to control using herbicides. A combination of several different management practices is needed.

Scouting

Knowledge is half the battle. Each year survey the weed populations present in production fields. This practice will help detect changes in weed populations, weed escapes, and possible herbicide resistant weeds before they are a significant problem in your fields. Herbicide selection is based on identification of the weeds present in your field; therefore, documenting weed populations over time is critical in weed management decision-making.

Cultural Practices for Weed Management in Soybean

Crop Rotation

When the same crop is grown in sequence year after year, certain weed species or communities of weeds tend to be favored and build-up over time. This is also true of many disease and insect pests. Changing or rotating to a different crop breaks the cycle which favors certain weed population(s) in that production practice. For example, planting wheat in the same field for several years in a row, mimic weeds like annual ryegrass proliferate because of the similar lifecycle and seed size. Rotating to a broadleaf crop in this scenario would allow the use of different herbicides that would control ryegrass. A well-planned crop rotation can reduce weed pressure over time.

Row Spacing and Seeding Rate

Several troublesome annual weed species in soybean rely on light for a germination cue. Palmer amaranth is a small-seeded broadleaf weed that will not germinate unless there is light reaching the soil surface. Fortunately, soybean is a versatile crop that can be planted in different row spacing configurations. Narrow row soybean (<15 inches) reaches canopy or row middle closure at a faster rate than wide row soybean (>30 inches). Canopy closure limits or minimizes the amount of light reaching the soil surface and inhibits germination of light-depended weed seeds. In addition, canopy closure allows the crop to intercept nearly 100% of the light reaching the crop which translates into higher yield potential. Check the seed bag for information on proper seeding rate for the soybean variety. Following the recommended seeding rate on the bag ensures the final crop population will be sufficient to shade out the soil and eliminate potential in-row gaps between plants.

Tillage

The use of mechanical implements to manage weeds is a very old practice. Before herbicides were common, tillage (e.g., plowing, disking, cultivating) were used throughout the growing season to control weeds. Conservation tillage and the introduction of broad-spectrum herbicides have eliminated most of these practices from soybean production. In cases where herbicide-resistant weeds are a problem, judicious use of some tillage is warranted. For example, selective deep tillage can bury weed seeds to a depth where they cannot germinate. Afterwards, a cover crop can be planted to minimize potential soil erosion. Recently, cultivation implements have been introduced that allow tillage and herbicide application between rows in trashy or no-tillage soils.

Date of Planting

Soybeans are available in different maturity groups ranging from 00 to IX. In South Carolina, maturity groups V through VIII are the most common varieties and depends on planting date, cropping system, and location in the state. Full-season soybean are planted in April and May are typically V and VI's whereas VII and VIII maturity groups are preferred for later planting dates (June and July). Soybeans planted early allow the crop to germinate and develop a canopy before summer annual weeds emerge and become competitive. For double-crop or late-planted soybean, broad-spectrum burndown herbicides (i.e., paraquat, glyphosate) are available to control the emerged weeds before planting to ensure a weed-free planting.

Herbicide Tolerance Traits in Soybean

There are several important factors to consider before developing a weed management strategy including variety selection. Most soybean varieties are sold with herbicide tolerance traits in the seed. Roundup Ready was the first herbicide tolerance trait package introduced in soybean in 1996. Since that time, other herbicide tolerant traits have been added to soybean (table 2) including tolerant to glufosinate (Liberty-Link), dicamba (RR2 Xtend/RR2

XtendFlex), and 2,4-D (Enlist E3). Depending on the weed spectrum in your field, selecting the variety with the right herbicide tolerance trait package for your field operation.

Table 2. Herbicide tolerant trait packages available in soybean.

Platform	Tolerance to
Roundup Ready 2	Glyphosate
Roundup Ready 2 Xtend	Glyphosate/Dicamba
Roundup Ready 2 XtendFlex	Glyphosate/Dicamba/Glufosinate
Enlist E3	Glyphosate/2,4-D/Glufosinate
Liberty-Link	Glufosinate
STS	Scepter*

*Allows a higher application rate of Scepter compared to a non-STS variety.

Herbicides for Weed Management in Soybean

Herbicides are a cost-effective option for managing weeds in soybean. When purchasing and using herbicides, it is important to read and follow the use guidelines on the product label. Herbicide selection should be based on the weeds present (or will be present after the crop emerges). As discussed previously, scouting and correct identification of weeds in soybean production fields is important because most herbicides are selective for certain weed or group of weeds. For example, chlorimuron (e.g., Classic) is an effective postemergence herbicide on sicklepod, bristly starbur, and annual morningglory, but weak on Palmer amaranth. Similarly, fomesafen (e.g., Reflex) postemergence is effective on Palmer amaranth but has reduced activity on vining weeds, such as annual morningglory. Herbicides are available for several different application timings relative to crop planting and include preplant burndown, preplant incorporated, preemergence, and postemergence.

Preplant Burndown

Planting into a clean field is important to ensure competition-free environment for the crop. Preplant burndown is an application which occurs 7 to 30 days before planting and controls the existing weeds. The type of herbicides used will dictate how long the waiting interval is before planting. Herbicides, such as glyphosate, need 14-21 days after application for maximum activity on weeds, especially large ones. If the time before planting is short, paraquat (e.g., Gramoxone) is a fast-acting (e.g., a few days), broad-spectrum herbicide effective on annuals, but limited activity on large, flowering weeds or perennials. The time of year for the preplant burndown application will determine the weed spectrum present. Winter annual and biennials are the weeds present in early planted (April) and summer annuals are present in late-planted soybean (June-July). Consult the product label for specific details on recommended waiting periods before planting.

Preplant Incorporated

In conventional tillage, herbicide can be applied to the soil surface and incorporated or mixed with the upper soil profile. The advantage of incorporation of the herbicide is no need for rainfall or irrigation to activate it. In dry planting conditions, the soil applied herbicide can be activated, but incorporation is only conducted in a conventional tillage production system. Some herbicides are sensitive to photodegradation when left on the soil surface (e.g., trifluralin, Treflan) and need to be incorporated with the soil profile for optimum activity on weed seeds in the soil seedbank.

Preemergence

A product that is applied shortly after the crop is planted is a preemergence herbicide. These herbicides are designed to be applied to the soil surface and are activated by a rainfall or irrigation. Preemergence herbicides control or prevent weed seed germination in the upper soil profile (usually less than 1 inch). These reduce the overall germination cohort of the weed populations before the postemergence herbicides are used. Small-seeded weed seeds (e.g., Palmer amaranth, crabgrass) are generally more affected by these herbicides (e.g., s-metolachlor, Dual Magnum) than large-seed ones (e.g., cocklebur).

Postemergence

After weeds emerge, postemergence herbicides are used to control weeds and minimize competition with the crop. As discussed previously, postemergence herbicides vary in weed selectivity. For example, clethodim (Select) will only control grass weeds. Soybean varieties contain genetic tolerance to several broad-spectrum postemergence herbicides including glyphosate (e.g., Roundup) and glufosinate (Liberty). These herbicides have activity across many grasses and broadleaf weeds. Soybean varieties were recently introduced with tolerance to dicamba (Xtend) and 2,4-D (Enlist). This tolerance was developed as a response to glyphosate resistance in Palmer amaranth. Growth stage of the weed greatly influences the success of a postemergence herbicide. Small, actively growing weeds are easier to control compared to large and/or drought stressed weeds which often need retreatment for satisfactory control. Consult the product label for information on recommended spray additives and adjuvants, effective weed spectrum, and other application parameters.

Soybean Nematode Control

John D. Mueller, PhD

Yield losses due to nematodes in South Carolina soybeans are caused primarily by southern root-knot, soybean cyst, Columbia lance, and reniform nematodes. Sting, lesion, and peanut root-knot nematodes also cause losses in some fields. Soybean is an excellent host for these nematode species and therefore often sustains significant yield losses. In a survey of 500 soybean fields in South Carolina more than 90% of the fields had one of the previously listed nematode species present. Almost a third of the fields had at least one nematode species at damaging levels.

Figure 3. Dead, stunted, and chlorotic plants caused by root-knot nematode.

Determining If You Have a Nematode Problem

Symptoms caused by nematodes typically include stunted or chlorotic (yellow plants). Patches of damaged plants are typically elongated ovals stretching in the direction of tillage in a field. By the time this level of damage is detected, nematodes are usually prevalent in the field and are causing greater than a 20% yield loss. Therefore, detection of a nematode problem prior to symptom development is highly desirable. The reniform nematode typically does not produce such distinct symptoms. It is often spread almost uniformly across a field. Of all the nematode species only root-knot nematodes produce a diagnostic symptom, root galls, that can be easily seen with the unaided eye. Even then you cannot be sure if you have southern or peanut root-knot nematode, or if other nematode species are present.

The only accurate way to determine if nematodes are causing a problem in your field is by submitting a soil sample to a nematode assay laboratory. There are two basic types of nematode samples. The first is a predictive sample. This sample is taken in the Fall and used to predict the degree of yield loss that may occur in the crop the following year. A predictive sample will determine the density of each nematode species present. These numbers can then be compared to nematode densities that are associated with known levels of yield losses (table 1). The second type of nematode sample is a diagnostic sample. These samples are taken during the growing season to determine if areas of poor growth, stunting, or chlorosis are due to nematodes or some other problem. Nematode problems are so common in South Carolina that a nematode sample should be included in almost any attempt to diagnose the cause of poor growth in a field.

Samples can be submitted through your county agent to the Clemson University Agricultural Services Laboratory. The charge is $20.00 per sample. Since most samples represent 10 to 20 acres this is an investment of $1.00 to $2.00 per acre to determine if you can avoid losing 25 to 50% of your yield. The optimum time to sample for nematodes is from three-weeks-prior to harvest until three-weeks-after harvest. A typical nematode sample should consist of one sample for each field or 10-acre section of larger fields. Break fields up into obvious sections as determined by soil types, drainage or cropping history. Use a shovel or soil probe to get soil from within the crop row to a depth of about 8 inches. Samples should be taken approximately two to four inches from the plant stems. You should feel the probe or shovel cut through roots as you insert it into the ground. Each sample should be composed of 10 cores mixed together in a bucket. A 1-quart composite sample should be taken from the bucket and placed in a plastic bag, sealed shut and labeled.

When submitting a diagnostic sample, it is advisable to include some live crop roots in the sample, especially if galling is present and species determination of root-knot nematode is being requested. For diagnostic samples you should not sample the center of the "dead" spots. Instead sample the edges of the affected area and submit a second sample from a "healthy" area. Comparison of the nematode populations in these two areas will allow for a better diagnosis of the problem.

Results from predictive samples include control recommendations based on the nematode species and population levels that are found. A nematode assay will allow you to select the most appropriate resistant varieties, plant effective crop rotations, and make decisions on when to use a nematicide.

Table 1. Damage thresholds for nematode species in corn, cotton, soybean and peanut in typical Coastal Plains soils in South Carolina. Thresholds are per 100 cm3 soil.

Nematode species	Field Corn	Cotton	Soybean	Peanut
Southern root-knot	300	100	75	**Nonhost**
Peanut root-knot (race 2)	200	**Nonhost**	50	**Nonhost**
Reniform	**Nonhost**	250	200	**Nonhost**
Soybean cyst	**Nonhost**	**Nonhost**	25	**Nonhost**
Sting	4	4	4	8
Lesion	200	150	200	25
Stubby Root	40	50	50	50

Modified from "Nematode Guidelines for South Carolina", EC 703, Clemson Extension Service: https://www.clemson.edu/public/regulatory/plant-problem/pdfs/nematode-guidelines-for-south-carolina.pdf

The five nematode genera that cause soybean yield losses, their symptoms and controls are described in the following paragraphs.

Root-Knot Nematodes

Distribution

Root-knot nematodes can occur in alm Root-knot nematodes can occur in almost all soils in the Coastal Plains and even in some of the lighter soil types in the Piedmont. There are several species of root-knot nematode that can affect soybean in South Carolina. The most important species is "southern" or "common" root-knot nematode. This is *Meloidogyne incognita*. A second species is common in South Carolina. It is race two of the "peanut" root-knot nematode, *Meloidogyne arenaria*. Race one of peanut root-knot nematode goes primarily to peanut but is very rare in South Carolina. Race two goes to soybean but not peanut and is common in several areas of the state including Lexington County, parts of Bamberg and Orangeburg Counties, and areas where tobacco has been grown. Both *M. incognita* and *M. arenaria* occur in the northeast corner of the state where tobacco has been grown. Cotton is not a host for *M. arenaria* and *M. arenaria* is not common in fields that have been rotated with cotton. Other species such as *M. hapla*, the northern root-knot nematode and *M. javanica* have been detected sporadically in the state. Recently *M. enterolobii*, the guava root-knot nematode was found in Darlington County. This species is frequently seen in North Carolina in sweet potato fields and in soybean fields that are rotated with sweet potato. Guava root-knot nematode can be very damaging to most of the crops it occurs on. For more information on guava root-knot nematode go to the FIND*Me* website, www.findmenematode.org.

Symptoms

Damage from root-knot nematode can be severe, including death of infected plants. Damage levels increase as the plants are exposed to moisture or heat stress. Affected soybeans can be stunted and yellow. They may not die until later in the growing season when they are fully grown and most susceptible to moisture stress. Plants that have been killed by southern blight (white mold) or red crown rot often exhibit high levels of galling that predisposed the plants to these fungal root rots. Roots usually exhibit visible galls. Galls should not be confused with *Rhizobium* nodules. Galls are an integral part of the root; nodules are not. If you run your fingers down a root pinching the root as you go nodules will pop off, but galls will stay in place.

Figure 4. Galling on soybean caused by Peanut root-knot nematode.

Control Measures

The most cost-effective way to control root-knot nematodes is to use resistant varieties or to rotate to a non-host crop. Most soybean cultivars exhibit only partial resistance to southern root-knot nematode and may not provide enough control where pressure is heavy or where other nematode species are also present. Table 1 gives threshold values for southern root-knot nematode in soybean. Where pressure is low to moderate, resistant cultivars should provide sufficient levels of control. Where southern root-knot nematode densities are high (2 to 3 times the threshold or more) the field should be rotated to a non-host crop (table 2) or a nematicide should be added to the resistant cultivar (table 3). If a nematicide is used it should always be applied to a root-knot nematode resistant cultivar. Susceptible cultivars may respond to a nematicide, but typically yields of a susceptible cultivar plus a nematicide will be less than those of a resistant cultivar without a nematicide. The most cost-effective response to a nematicide is typically on a resistant cultivar. In-row subsoiling or any other cultural practice that helps reduce stresses can help limit damage due to root-knot nematodes. Nonhost crops that will reduce nematode population densities are listed in table 2. The new southern root-knot nematode resistant cotton varieties are very effective in reducing residual root-knot nematode populations at harvest. They may be used in place of a non-host crop in a rotation to reduce root-knot populations.

Table 2. Host status of common row crops in South Carolina to commonly occurring nematode species. Growing the non-host species will reduce nematode levels in a field.

Common name ***Genus species***	**Soybean**	**Cotton**	**Corn**	**Peanut**
Southern root-knot *Meloidogyne incognita*	Host	Host	Host	**Non-host**
Peanut root-knot *Meloidogyne arenaria* (race 2)	Host	**Non-host**	Host	**Non-host**
Guava root-knot *Meloidogyne enterolobii*	Host	Host	Host	**Non-host**
Columbia lance *Hoplolaimus Columbus*	Host	Host	Host	**Non-host**
Reniform *Rotylenchulus reniformis*	Host	Host	**Non-host**	**Non-host**
Sting *Belonolaimus* spp.	Host	Host	Host	Host
Lesion *Pratylenchus* spp.	Host	Host	Host	Host
Soybean cyst *Heterodera glycines*	Host	**Non-host**	**Non-host**	**Non-host**

Columbia Lance Nematode

Distribution

The Columbia lance nematode (*Hoplolaimus columbus*) occurs in most soybean growing areas of the state. Due to its large size it is restricted to coarse textured sandy soils with large pore sizes. *Hoplolaimus galeatus* is also common in South Carolina but occurs primarily in perennial plants such as turf. It is rarely seen in cotton or soybean fields in the Coastal Plains but has been detected in soybean and cotton fields in the Piedmont.

Symptoms

Affected plants can be stunted and yellow, but plants usually do not die. Damage is often exhibited as uneven (up and down) growth within a row. Roots are sometimes bunched near the soil surface and show poor taproot development. Roots may also have a hairy or fibrous appearance (with many small rootlets). Infection by Columbia lance nematode appears to inhibit nodulation by *Rhizobium* and subsequent N fixation.

Control

Try to use a cultivar tolerant of Columbia lance nematode. In-row sub-soiling will reduce, but not eliminate, losses from Columbia lance nematode in most Coastal Plain soils. Planting early, prior to mid-May can reduce losses. However, later planting dates such as those in a wheat/soybean double-cropping system may favor infection and damage by Columbia lance nematode. Therefore, avoid double-cropping soybeans in Columbia lance nematode fields. Use a low rate of a nematicide at planting on a tolerant cultivar (table 3). Crop rotation is normally not effective since peanut is the only nonhost crop (table 2). Soil-borne diseases such as red crown rot (black root-rot on peanut) build up under soybean and can cause serious problems in subsequent peanut crops.

Soybean Cyst Nematode

Distribution

The soybean cyst nematode (*Heterodera glycines*) occurs throughout the Coastal Plain and the lower Piedmont counties. Unlike many nematode species it is not limited to specific soil types.

Symptoms

Affected plants are usually stunted and have yellow leaves. Close examination of the roots may show reduced nodulation and tiny white to yellow immature female cyst nematodes. As these females age, they turn light brown, then darker brown and die. This dead female is the characteristic “cyst” of soybean cyst nematode. The optimum time to find cysts is to view roots 30- to 45-days after planting. Do not confuse cysts with nodules. Nodules are much larger than cysts. The smaller cysts are harder to see. Female cyst nematodes lay eggs in an egg mass. Some of the eggs hatch immediately and the young cyst nematode larvae continue the life cycle, which takes about 30 days to complete. Other eggs are retained in the dead female (the cyst) where the leathery cyst wall helps protect the eggs from damage and infection from soil microbes. Some of these eggs will not hatch for several years. Once a field is infested with soybean cyst nematode it will be 5 to 10 years before all of the eggs have hatched. Where soybean cyst nematode is suspected in a field, have the soil tested for nematodes.

Races and HG types

Many varieties of soybean have genes that confer resistance to soybean cyst nematode. Unfortunately, most of these varieties share the same resistance gene which is derived from the breading line PI 88788. As these varieties have been grown repeatedly in the same fields, cyst nematodes which can overcome the PI 88788 gene are being selected for, and the resistance is no longer effective. HG types describe the resistance gene present in a variety. In the past in South Carolina race 3 was the most common race of soybean cyst nematode. The constant use of resistance from PI 88788 has selected for other races such as 6, 9, and 14 which are not controlled by PI 88788. In these field infection, reproduction, and subsequent yield losses can be severe. To avoid this situation, if a grower wants to plant soybeans more than 1 year in a row in the same field, they need to find a variety with a source of resistance other than PI 88788. These are available, but you will need to check with your preferred seed company to see if they have such a variety.

Control

Soybean cyst nematodes are easily spread in soil clinging to equipment, runoff water, blowing dust, or soil peds that may contaminate seed. Make sure seed for planting are free of all foreign matter. Clean all equipment before moving from an infested field, or even a suspected field, to another field. Avoid monocropping soybeans, especially the same cultivar or cultivars with the same source of resistance to soybean cyst nematode. Rotation with a non-host crop such as corn, cotton, peanut, or sorghum will greatly reduce inoculum for the next year’s crop. In fields with high infestations of soybean cyst nematode, where yield losses are extensive, you may need two or more years of a non-host crop to return to non-damaging levels of soybean cyst nematodes.

A nematicide can be used for cyst nematode management, especially if other harmful nematodes are present in the field; see table 3. Yield potentials and commodity prices must be high to justify the use of Telone II. However, three gallons per acre of Telone II will provide excellent control of most nematode species present. Three to five lbs. per acre of AgLogic 15GG can be used at planting to help control nematodes. Only use AgLogic 15GG with a resistant cultivar. If Temik 15G is used on a susceptible cultivar yields may not be as high as with a resistant cultivar alone. Seed treatments should only be used where nematode population densities are low or in combination with a resistant variety.

Use of a wheat-soybean double-cropping system may reduce cyst nematode populations. The high soil temperatures at the late planting date for the soybeans in this system are detrimental to cyst nematode. However, later planting dates may favor infection and damage by Columbia lance nematode.

Reniform Nematode

Distribution

Reniform (*Rotylenchulus reniformis*) nematode is a commonly occurring problem in the counties between the Santee lakes and the North Carolina border. It is also common in Calhoun and Orangeburg Counties. In the early 1980s reniform nematode was thought to be restricted to clay soils and river bottoms. Today we know that reniform nematode can occur in most of our Coastal Plains soils and in some Piedmont soils. Reniform has a relatively wide host range and cotton is an excellent host (table 2). In 2021 several cotton varieties have been released that are resistant to reniform nematode. While this is effective in maintaining cotton yields at the end of the year population densities of reniform nematodes in these fields are still too high to consider using these varieties as a "nonhost" crop in a rotation t to control reniform nematode.

Symptoms

Reniform typically produces the least distinctive damage of any of the nematode species on soybean. Reniform populations build up rapidly and instead of oval areas containing damaged plants, the entire field will be stunted or discolored. Detectable stunting typically occurs only where the soil type is poor, and plants are under stress even without nematode damage.

Control

Soybean varieties with resistance to soybean cyst races 1 and 3 may also be resistant to reniform nematode. It may require 2 years rotation to a non-host crop to reduce the reniform nematode population density to a level where a reniform nematode susceptible soybean variety can be grown. Use of nematicide may help to reduce yield losses due to reniform nematode (table 3).

Sting nematode

Distribution

Sting nematodes (*Belonolaimus spp.*) are restricted to soils with very coarse textured sands. These soil types are found only in the Coastal Plain.

Symptoms

Very low populations of sting nematode can cause extensive damage on soybean (table 1). Severe stunting and chlorosis are common. Distribution within a field will be limited only to areas of the field with very coarse textured sand.

Control

The host range for sting nematode includes corn, coastal Bermuda grass, cotton, okra, peanut, soybean, and watermelon. No non-host crops are available for rotation in South Carolina (table 2). In-row subsoiling is a must. Use of a nematicide may help (table 3).

Table 3. Nematicides available for use controlling Soybean cyst, Southern root-knot, Columbia lance, reniform, sting, and lesion nematodes.

Nematicide	Active ingredient	Rate per acre for 38-inch rows	Comments
Telone II	1,3-dichloropropene	3.0 – 6.0 gallons	Release fumigant at least 12 inches from the soil surface. Must be applied 10 to 14 days prior to planting.
AgLogic 15G & AgLogic 15GG	Aldicarb	6.0 lbs.	Apply a 4– to 6-inch T-band over open seed furrow and immediately cover with soil.
Avicta Complete Beans 500	Abamectin Thiamethoxam Mefenoxam Fludioxonil	6.2 fl. oz. per cwt. of seed	Application by commercial seed treaters only.
AVICTA 500 FS	Abamectin	See Label	Applied only as a commercial seed treatment. Controls only nematodes.
Bio ST Nematicide 100	Heat killed *Burkholderia* spp. strain A396 + spent fermentation media	8.0 oz. per 100 lbs. of seed	Can be applied as commercial seed treatment or as a seed dressing at plant.
Clariva pn	*Pasteuria nishizawae* – Pn1	1.0 to 3.0 fl. oz. per cwt. of seed	Effective only against soybean cyst nematode.
Clariva Elite Beans	*P. nishizawae* – PN1 Thiamethoxam, Sedaxane Mefenoxam Fludioxonil	5.6 fl. oz. per cwt. of seed	Includes the nematicide Clariva pn, the only nematode this will control is soybean cyst nematode.
ILeVO	Fluopyram	1.08 to 3.62 fl. oz. per cwt	Apply using commercial slurry or mist-type seed treatment equipment. May help control sudden death syndrome
Poncho Votivo Seed Treatment	Clothianidin *Bacillus firmus* I-1582	1.02 fl. oz. per 140,000 seed	Applied only as a commercial seed treatment. Contains materials to control nematodes and thrips.
PONCHO/VOTiVO	Clothianidin *Bacillus firmus* I-1582	2.4 fl. oz. per 100,000 seed	Applied only as a commercial seed treatment. Contains materials to control nematodes and thrips.
Saltro	Pydiflumetofen	1.52 fl. oz Per cwt seed	For control of sudden death syndrome (*Fusarium virguliforme*), and plant-parasitic nematodes including soybean cyst, reniform, southern root-knot, lesion and lance nematodes.

Soybean Disease Control

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Soybean is susceptible to many diseases beginning chronologically with seed rots and seedling diseases. As the plant develops and matures, leaf, pod, and stem diseases often become common, especially during wet growing seasons. In most cases a disease will damage or kill individual plants or groups of plants in a row or ovoid pocket. However, if root-knot nematodes are present in addition to fungal diseases of the root or lower stem, such as southern blight or red crown rot, extensive damage may occur. Leaf diseases such as brown spot, can have little or no effect upon yield while other leaf diseases such as frogeye leaf spot or soybean rust can prematurely defoliate large areas of a field, drastically reducing yield. Detection and accurate identification of diseases can be difficult. Many symptoms such as interveinal necrosis occur with several diseases. When an accurate identification is needed you should work through your county agent to utilize their expertise to either identify the problem on site or submit an accurate sample to the Clemson University Plant Problem Clinic.

Seedling diseases

Profit margins on soybean are too narrow to allow replanting of most fields due to poor stands. Growers get only one chance to establish the desired stand in a field and must minimize the potential for seedling diseases. Seedling diseases can occur over a wide range of conditions and plant growth stages. Included in the seedling disease category are: seed rots that occur after seed has been planted but prior to germination; seedling decay which occurs between germination and emergence; and damping off which occurs in the first 2- to 3-weeks after emergence. Accurately identifying the microbial species that has caused any of these problems is difficult: especially if the plant has already died. However, differentiating among the three major post-emergence pathogens can be fairly predictable depending upon the temperature and moisture conditions.

Seed rots occur prior to germination. They are typically caused by a combination of various fungi and bacteria. The seed is frequently of low vigor. When low vigor is the problem additional seed treatments with fungicides will not improve stands. Seed rots often occur when seed are placed under stresses. These can be temperature extremes, too hot or too cold, or in very wet or dry conditions. Unfortunately, avoiding early planting dates or planting prior to either extremely hot and dry or cool and wet periods as well as using only high-quality seed are the only way to avoid seed rots.

Pre-emergence damping off is typically caused by *Pythium* spp. in cool wet weather. Seeds begin germination but either due to poor seed quality or diseases never produce a seedling capable of cracking the soil surface. The *Pythium* fungus is normally a problem only in very early planted soybeans.

Post-emergence damping off is typically caused by *Pythium* species in cool, wet weather. A sunken lesion or canker develops near the soil line and appears to be a “wet rot”. In warmer or drier weather *Rhizoctonia solani* is more typically the cause of post-emergence damping off. There is still a lesion or canker near the soil line, but it does not have the appearance of a wet rot.

Phytophthora root rot is caused by the fungus *Phytophthora sojae*. It is a common disease in the Midwest on their heavy soils which retain moisture. It is much less common in the Coastal Plains soils of South Carolina since their sand content allows for better drainage and higher temperatures than those favored by the fungus. The clay soils of the Piedmont are more favorable to Phytophthora root rot than the sandy soils of the Coastal Plain. Phytophthora root rot typically is detected from plants in the seedling stage to plants in early pod set. Plants have leaves that exhibit interveinal necrosis and a dark brown discoloration progresses up the outside and the inside of the stem. Root systems are normally extensively decayed. Resistance is common in lower maturity group soybean varieties but is not as common in Maturity Group VI, VII, and VIII soybeans. The existence of races of the fungus makes utilization of resistance difficult.

Seedling disease control: To minimize all types of seedling diseases use a seed-treatment fungicide on seed with less than 80 percent germination and on all soybean seed to be planted under cool, wet conditions. The fungi which cause most seedling diseases overwinter on debris from the previous crop. Use a seed-treatment fungicide when soybeans are planted with conservation tillage since vigorous stands are critical to early season weed control. Seed treatments do not compensate for poor seed quality. The fungicides available for seed treatments are listed in table 1. Remember the fungicides which control *Rhizoctonia solani* do not control *Pythium* or *Phytopthora* species and vice-versa. Therefore, the most effective seed treatments usually include at least two fungicides with one from each category. Closely follow the manufacturer's label for doses and application procedures in treating seed. Efficacy of all seed treatments requires thorough mixing of the fungicide and seed so that all seed are adequately treated.

Leaf diseases

Soybean rust

Soybean rust, previously referred to as Asian soybean rust, has received a lot of attention since it was first discovered in the United States in the late Fall of 2004. It is caused by the fungus *Phakopsora pachyrhizi*. Soybean rust can only survive for extended periods of time on live host tissue.

Figure 1. Premature defoliation due to Asian Soybean Rust in the center plot.

Therefore, it cannot overwinter anywhere above the freeze line (approximately Tampa Bay, Florida) since its primary hosts, kudzu and soybean, will be dead and defoliated. Each year new inoculum (rust spores) must blow in from infected areas such as south Florida, Mexico, or South America to start the disease over again in the Southeastern United States. Infections and sporulation by soybean rust are favored by cooler, wet weather. Hot dry weather will stop the spread of the fungus. Soybean rust is typically first observed in South Carolina in mid-August to as late as the first week in October. However, periods of hot, dry weather in September often slow infection rates and spread so that overall effects on yield statewide are minimal. Management of soybean rust is primarily through the use of foliar fungicides applied during flowering. A list of fungicides available for rust management in South Carolina is presented in tables 2 and 3. Growers need to be very careful when choosing fungicides for soybean disease control. Some fungicides such as Topsin 4.5 FL provide excellent control of many diseases but are not effective against rust (table 2).

The South Carolina Soybean Board has funded a soybean rust monitoring program for the last several years. It is run by Joe Varn and Jonathan Croft, Agronomic Row Crop Agents in Orangeburg and Allendale/Bamberg/Barnwell Counties. They survey from lower Hampton County to Anderson and Clarendon Counties from early July to October. Their results are reported each week in their electronic "Soybean Rust Newsletter". Currently there are no varieties with functional resistance to soybean rust.

Bacterial blight

Bacterial blight is caused by the bacterium *Pseudomonas syringae* pv. *glycinea*. This bacterium over winters on infected soybean tissue on the soil surface but can also be seed borne. Infections occur through stomates and wounds. Very young plants can be infected. Symptoms appear first as water-soaked lesions. Yellow halos develop around the lesions and the center of the lesions turn brown and eventually fall out. Therefore, in advanced cases of the disease the leaves appear tattered or shot-holed. When infected tissue is place in water under a microscope, bacteria will be visible streaming out of the lesions. Disease development is favored by cool (75 to 79° F), wet and rainy weather. Like many diseases spread or development will slow or halt in hot dry weather. Bacterial blight resembles brown spot, but bacterial blight will move up the plant much quicker. Management of bacteria blight is through the use of high-quality seed, avoiding excessive stands and narrow rows, and destroying or plowing under crop residues in the fall. Use of foliar antibiotic sprays has usually not been successful in controlling bacterial blight.

Bacterial Pustule

Bacterial pustule is caused by the bacterium *Xanthomonas campestris* pv. *glycines*. Like bacterial blight it over winters on seed and in soybean debris. Disease development is favored by warm (86 to 91° F), wet weather with splashing rains. Unlike bacterial blight hot weather will not slow down the development of bacterial pustule. Bacterial blight and bacterial pustule may occur on the same leaf. Symptoms include raised areas on the underside of the leaves in which pustules eventually form. Bacterial pustules can easily be mistaken for pustules caused by soybean rust. You will need help from your county agent to differentiate the two diseases or a sample will need to be sent to the Plant Problem Clinic. To minimize the risk from bacterial pustule plant high quality seed of resistant varieties and destroy soybean debris in the Fall. Use of foliar antibiotic sprays has usually not been successful in controlling bacterial pustule.

Downy Mildew

Downy mildew is caused by the fungus *Peronospora manshurica*. This disease is very common in South Carolina and usually occurs during periods of three or more days of high humidity or thunderstorms in July and August. The disease may appear suddenly and spread rapidly. The inoculum is airborne and blows in from other affected areas. Only young leaves are susceptible so the disease will first appear in the top of the canopy. Symptoms include small light green to yellow lesions on the upper leaf surface that have a white tuft of the fungus visible on the bottom side of the leaf. You may need a magnifying glass to see this white tuft. Pods can be infected but show no symptoms. Infected seed have a white crust present on the seed. When the weather becomes dry the white tuft will shrivel up and fall off but the yellow spots on the leaf surface will remain. Although the yellow spots may cover a large area of some leaves, yield losses due to downy mildew are minimal. The yellow spots are often mistaken for soybean rust.

Soybean rust can be differentiated from downy mildew because only soybean rust has pustules present on the bottom side of the yellow spots. Soybean rust does not have the mycelial tufts on the undersides of lesions. Spraying fungicides for downy mildew is usually not cost effective unless soybeans are being grown for seed. Seed treatment fungicides can help eliminate seed-borne downy mildew. Soybean varieties vary greatly in their susceptibility to downy mildew but information on current varieties is difficult to obtain.

Brown Spot

Brown spot is caused by the fungus *Septoria glycines*. Brown spot may be the most common soybean disease in South Carolina. It occurs in almost every field. It overwinters on seed and in crop debris. Severity of brown spot increases as plants mature and senesce. Symptoms of brown spot are rather indistinct. Lesions are irregular in shape and size but tend to enlarge into “brown spots”. Brown spot starts in the lower canopy and moves up the plant with time. Very small fruiting structures called pycnidia are present in the larger lesions. They are impossible to see without a dissecting microscope. They resemble the pycnidia present with pod and stem blight but do not occur in rows. Infected leaves often senesce and drop off the plant prematurely.

However, yield losses are usually minimal since photosynthesis in these leaves was no longer efficient. Control is through the use of high-quality seed and destruction of soybean debris in the fall. Several fungicides will control brown spot but usually yield losses are low and do not warrant control (table 2). Varieties seem to vary in their levels of susceptibility to brown spot, but there are no reliable ratings available for use.

Frogeye Leaf Spot

Figure 2. Frogeye leaf spot on a susceptible cultivar.

Frogeye leaf spot is caused by the fungus *Cercospora sojina*. This fungus overwinters on infected seed and in soybean debris. Symptoms of frogeye leaf spot are very distinct with generally circular lesions with a white to grey center and dark reddish-brown margins. As the lesions age the center may turn darker.

Symptoms occur in midseason and then become more severe after flowering. Varieties vary in their susceptibility from almost immune to moderately susceptible to extremely susceptible. In the right weather conditions, very overcast or rainy weather, extremely susceptible cultivars

Soybean can be almost totally defoliated by frogeye leaf spot. Control is by planting resistant varieties, using high quality seed and destroying soybean debris in the Fall. Avoid extremely susceptible cultivars. Foliar fungicide sprays after flowering can help limit the severity of frogeye leaf spot but are economical only on very susceptible varieties when disease severity is high (table 2).

Cercospora Blight and Purple Seed Stain

Figure 4. Bronzing and leaf discoloration due to Cercospora leaf blight.

Cercospora blight & purple seed stain are caused by the fungus *Cercospora kikuchii*. This fungus overwinters in debris and seed coats. Symptoms of cercospora blight can be difficult to distinguish from nutrient deficiencies or ozone damage.

Symptoms typically appear only late in the growing season with premature defoliation of the upper canopy during pod fill. Leaves appear to be a reddish-purple or bronze especially after flowering with the discoloration worsening as plants mature. Reddish-purple lesions may develop on major veins on the underside of leaves. Pods may exhibit round, reddish-purple lesions which later turn purple/black. Infected seeds will exhibit a distinctly purple stain over some or all of the seed coat. If infected seed are to be planted, they need to be treated with a fungicide. Several foliar fungicides are effective in controlling this disease but predicting severity so that preventive sprays can be made is difficult (table 2). Some varieties appear to be less susceptible than others: however, reliable lists of resistant varieties are not available.

Target Spot

Target spot is caused by the fungus *Corynespora cassiicola*. This disease appears to be on the increase in the Southeastern United States. It has an extremely wide host range and infects many plant species. The fungus overwinters on soybean debris and seed. It can survive in a fallow field for two years. Symptoms include round to irregular lesions which may have alternating light and dark rings (a target spot) similar to that caused by *Alternaria* species on soybean and many vegetable crops. The disease appears to be favored by wet weather in mid to late season and severity is worse in fields where the canopy has closed. Many varieties exhibit excellent resistance to target spot, however a reliable rating is not available for most varieties. When possible, choose a resistant variety. Use of foliar fungicides has not been a reliable control method for target spot.

Figure 5. Target spot.

Figure 6. Target spot damage. Left side of field exhibits dead leaves and defoliation on a susceptible variety; right side of field is a resistant variety.

Lower Stem Diseases

Red Crown Rot

Red crown rot, Cylindrocladium root rot, and CBR are all common names for a basal stem rot caused by the fungus *Cylindrocladium parasiticum* (formerly *Cylindrocladium crotalaria*). This fungus can persist in the soil for several years. Infection occurs in the taproot and spreads up the stem 8 to 12 inches, killing all roots and infected stem tissue. The first visible sign or symptom of red crown rot is yellowing of the leaves and eventual interveinal necrosis. This symptom is also common to red crown rot, and stem canker. Like southern blight, dead plants may be scattered throughout a field or in small clumps or oval shaped areas elongated in the direction of tillage.

The scattered dead plants often lead to an overestimation of the damage present in a field. Masses of small, ball-shaped, reddish-orange fruiting structures (perithecia) of the fungus usually develop on stems at the soil surface. Red crown rot infects many species of legumes as well as other plants; it can be spread by soil moved on plows and cultivation equipment and by surface water. No chemical controls are available. Some varieties appear more susceptible than others, but information on currently popular varieties is usually lacking. Red crown rot is usually considered to have little economic impact in South Carolina. Rotation to non-legume crops is the only economical control.

Southern Blight

Southern blight or southern stem blight is caused by the fungus *Sclerotium rolfsii*. This fungus survives in the soil on organic matter, is favored by hot weather stress and is recognized by the appearance of white mold on stems at the soil surface causing rotting of stems and roots. Small tan to brown, “mustard seed-like” fruiting bodies (sclerotia) are produced within the white mold growth. The disease is most often seen in June, July and August during very wet periods.

Southern blight is very common in fields with moderate to high levels of root-knot nematode. The first sign or symptom of the disease is interveinal necrosis in the leaves. This symptom is also common to red crown rot, and stem canker. Diagnosis as southern blight usually includes the presence of the white mold and sclerotia at the base of the stem. Plants with white mold surrounding the base of the stem often die. Dead plants may be scattered throughout a field or in small clumps or oval shaped areas in the direction of tillage. The scattered dead plants often lead to an overestimation of the damage present in a field. Although yield losses can be detected, in general southern blight often appears worse than it really is, and serious economic yield losses are not common in South Carolina. The sclerotia serve as survival structures for the fungus allowing it to survive over severe winters and for several years in the same field without a host.

Rotation with other crops such as cotton or corn will help reduce levels of inoculum in the field. Peanut is a host for *S. rolfsii* and will increase disease levels. No chemical controls are available.

Pod and Stem Diseases

Anthracnose

Anthracnose is caused by the fungus *Colletotrichum truncatum*. This fungus overwinters in seed and infected soybean debris. Symptoms of anthracnose are not well defined. Soybean is susceptible to anthracnose at all growth stages. Brown lesions develop on stems, pods, and even leaves. Infected petioles will form lesions below the leaflets and cause the leaflets to wither and drop. The remaining petiole often takes on a "shepherd's crook" shape. The fungus produces a black fruiting structure (an acervulus) similar in size to a rust pustule. However, unlike a rust pustule black hairs (setae) are present on the structure. The acervulus is diagnostic for this fungus and can be observed under a 20X magnifying glass or a dissecting scope. Anthracnose typically becomes apparent during flowering and becomes worse as the plants senesce. Wet weather during pod fill will increase the severity of anthracnose. Use of foliar fungicides applied after flowering will help alleviate the severity of anthracnose (table 2). Plowing under crop debris and rotation to a crop other than soybean will reduce inoculum levels. Resistant varieties are not available.

Pod and Stem Blight

Pod and stem blight is caused by the fungus *Diaporthe phaseolorum* var. *sojae* (sexual stage) also known as *Phomopsis longicolla* (asexual stage). Black fruiting structures (pycnidia) that resemble very small, rounded volcanoes are present in rows on affected stems and are more scattered on pods and leaves. Pycnidia of pod and stem blight resemble those of brown spot which occurs on leaves. Pycnidia of brown spot do not occur in rows nor are they normally found on stems. Pycnidia of pod and stem blight can be differentiated from anthracnose because the pycnidia occur in rows whereas the acervuli of anthracnose are more scattered and exhibit hairs (setae) which the pycnidia do not have. Like many fungal diseases this fungus overwinters on debris and can infect seed. Rotation with corn and plowing down residue will help reduce inoculum levels. Resistant varieties are not available. Use of foliar fungicides applied after flowering will help alleviate the severity of pod and stem blight (table 2).

Charcoal Rot

Charcoal rot is caused by the fungus *Macrophomina phaseolina*. This fungus can survive several years in dry soil as microsclerotia, a specialized fungal survival structure. However, microsclerotia can only survive several months in wet soil. This fungus can infect plants from the seedling stage all the way to maturity. Symptoms in seedlings include stunting and reddish brown to black discoloration in the lower stem. Taproots and lower stems of older plants can be reddish to black. Small black flecks or streaking are visible under the bark. These sclerotia are a survival structure and considered diagnostic for the fungus. Mid- to late-season charcoal rot is often linked to hot dry conditions. Charcoal rot has a very wide host range including over 500 crop species; however, rotation with most crops and deep tillage will reduce inoculum levels. Rotation with corn will not reduce inoculum levels. Use of irrigation will often minimize the stress caused by the fungus. Resistant varieties are not available. Use of foliar fungicides is not recommended since it is difficult to predict disease severity and often the stresses which increase infection levels and make symptoms visible limit yields.

Southern Stem Canker

Southern stem canker is caused by the fungus *Diaporthe phaseolorum* var. *caulivora*. This disease appeared throughout the Southern and Southeastern United States in the early 1980"s and caused severe yield losses in many fields. The epidemic was quickly brought under control with the utilization of resistant varieties in subsequent years. Today southern stem canker is not common in South Carolina. Most maturity group V, VI, VII, or VIII cultivars are resistant. In the Mid-South stem canker is still a problem. Susceptible varieties are often grown for several years when weather does not favor disease development. In subsequent years if weather is favorable for disease development yield losses can be catastrophic in a given field. The fungus can survive for at least a year on infected debris and may be introduced to a field on infected seed. Symptoms of stem canker begin in the mid- to lower stem nodes in July and August and move upward as the plant matures. Small, elliptical, dark brown cankers usually appear on the main stem near the base of nodes. Cankers enlarge as the disease spreads. Cankers can girdle the stem. Leaves of infected plants sometimes exhibit a flagging symptom with interveinal chlorosis and then die.

Other diseases such as red crown rot and southern blight cause similar symptoms. The leaves hanging on the plant after dying give the appearance of frost injury. To control stem canker, turn under infected soybean residue as soon as possible; rotate to non-host crops (e.g., corn or cotton) for one or two years; and plant resistant varieties where possible. Although most varieties in maturity group V or later are resistant, growers should double check all information on the varieties they choose to be sure they are resistant to southern stem canker. Foliar fungicides are not effective in controlling southern stem canker in South Carolina.

Sudden Death Syndrome

Sudden death syndrome is caused by the fungus is caused by the fungus *Fusarium virguliforme*. It is not a commonly occurring disease but is often confused with other stem and leaf diseases such as stem canker, brown stem rot, and southern blight. Symptoms are not distinct but may include chlorotic yellow spots on leaves normally beginning after R3 growth stage that resembles interveinal necrosis. Interveinal areas may die as the plant matures. Veins will remain green. Premature defoliation is common, and pods may be aborted. Petioles may be retained even after defoliation has started. Roots may be rotten and vascular tissues in roots and stem may be discolored. Plants can easily be pulled from the ground. If symptoms are observed it is a good idea to get a positive identification of the disease present since sudden death syndrome can persist in the soil for several years. Sudden death syndrome resistant varieties are available and should be used in fields where sudden death syndrome is present. Sudden death syndrome is often seen in the same fields as soybean cyst nematode. Seed treatments such as ILEVO and Saltro may help control both soybean cyst nematode and Fusarium virguliforme and thereby help reduce levels of sudden death syndrome.

Soybean Viruses

Several viruses are capable of causing yield losses in soybean. However, in most cases the yield losses are not severe. The symptoms often overlap between viruses and therefore positive identification of which virus you have may require laboratory testing.

Soybean Mosaic Virus (SMV)

Soybean mosaic is a very common virus in soybeans occurring in most soybean production areas of the world. Yield losses can range from less than 5% to more than 50% in some cases. Symptoms include a green-yellow mosaic pattern and premature defoliation may occur. Infected seeds may be mottled brown or black however this symptom can be caused by several diseases. Infected seeds may be smaller in size than healthy seeds and germination may be reduced. Introduction into a field is often through infected seed and once in the field it is spread from plant to plant by soybean aphids (*Aphis glycines*). The virus can overwinter on weeds in the field edge. Resistant varieties are available and are the most commonly used control measures. Nine strains of the virus are known to exist and some of these overcome all known resistance to SMV.

Bean Pod Mottle Virus (BPMV)

Bean pod mottle virus occurs commonly throughout the soybean growing areas of the United States. Yield reductions can range from 10% to 60% with the most severe damage occurring in plants infected early in the growing season. Symptoms range from mild chlorotic mottling in the upper canopy to puckering and severe mosaic in lower leaves. Symptoms can be acute on young leaves. “Green stem” is due to delayed maturity caused by BPMV can be observed close to harvest. A similar symptom can be produced by SMV. BPMV is transmitted by the bean leaf beetle (*Cerotoma trifurcata*). Transmission by bean leaf beetle is probably limited to short distances, 30 meters, in a field. Infected seed and weed hosts are often sources of the virus early in the season. No soybean cultivars are known to be resistant to BPMV. Early season control of bean leaf beetles can reduce levels of BPMV through the growing season. Delayed planting may help reduce damage from BPMV.

Co-infection by SMV and BPMV may result in very severe yield losses that exceed 66%. Symptoms may include severe dwarfing, foliar distortion leaf necrosis and mottling. Seed coat mottling can occur.

Tobacco Ringspot Virus (TRSV)

Tobacco ringspot can have a severe impact on soybean yield and quality. Infection by TRSV can result in bud necrosis, and excessive growth of leaves and buds. Stems may remain green for up to two weeks after normal senescence. Seed transmission is the most common mode of introduction into a field. TRSV can be transmitted by dagger nematodes and possibly by thrips No resistance is known in soybean to TRSV and use of TRSV free seed is the best control measure.

Soybean Vein Necrosis Virus (SVNV)

Soybean vein necrosis was first reported in 2008 and is now known to occur in all soybean production areas of the United States. Symptoms include vein clearing along the main veins, with veins yellowing and becoming necrotic later in the growing season. Premature leaf senescence may occur. Varieties vary in symptom expression. Symptoms may be more prevalent higher in the canopy since this is the preferred feeding sight of soybean thrips, the vector of SVNV. Ivyleaf morning glory and cowpea are both hosts for SVNV. Control of ivy leaf morning glory and thrips may help lower the incidence of SVNV.

Printed Literature

“A Farmer’s Guide to Soybean Diseases” edited by D. Mueller, K. Wise, A. Sisson, D. Smith, E. Sikora, C. Brandley and A. Robertson Published by the American Phytopathological Society Press contains excellent short articles on all of the known diseases and nematodes that affect soybean.

Websites

The Clemson University Cooperative Extension “2021 South Carolina Pest Management Handbook Soybean Disease Control (pages 276 to 282) and Soybean Nematode Control (page 283) is located at: http://www.clemson.edu/extension/rowcrops/.

The North Carolina State University “North Carolina Soybean Production Guide Disease and Nematode Management” is located at:

http://www.content.ces.ncsu.edu/north-carolina-soybean-production-guide/soybean-disease-and-nematode-management.

The University of Arkansas Soybean Handbook Disease Section (MP197 Chapter 10 “Nematode Control” and Chapter 11 “Soybean diseases) is at: http://www.uaex.edu/publications/MP-197.aspx.

Table 1. Fungicides available for controlling seedling diseases on soybean.

Product	Active Ingredient	FRAC Code	Fungi Controlled	Rate
Allegiance FL	Metalaxyl 28.35%	4	*Pythium spp.*	0.75 – 1.5 fl. oz. per cwt
Apron XL	Mefenoxam 33.3%	4	*Pythium* spp. *Phytophthora* spp.	0.16 – 0.64 fl. oz. per cwt.
ApronMaxx RFC	Mefenoxam 3.46% Fludioxonil 2.31%	4 12	*Fusarium* spp. *R. solani* *Pythium* spp. *Phytophthora* spp.	1.5 fl. oz. per cwt.
ApronMaxx RTA	Mefenoxam 1.01% Fludioxonil 0.73%	4 12	*Fusarium* spp. *R. solani* *Pythium* spp. *Phytophthora* spp.	5.0 fl. oz. per cwt.
ApronMaxx RTA + Moly	Mefenoxam 1.02% Fludioxonil 0.68% Molybdenum 4.67%	4 12	*Fusarium* spp. *Pythium* spp. *Phytophthora* spp. *R. solani*	5.0 fl. oz. per cwt.
Bean Guard/Allegiance	Carboxin 12.5% Metalaxyl 3.75% Captan 24.45% molybdenum 11.9%	**7** 4 M4	*Pythium* spp. *R. solani* *Fusarium spp.*	2.0 oz. per 60 lbs.
CruiserMaxx	Mefenoxam 1.7% Fludioxonil 1.12% Thiamethoxam 22.6%	4 12 Insecticide	*Fusarium* spp., *Pythium* spp., *Phytophthora* spp. *R. solani*	2.95 fl. oz. per cwt.
CruiserMaxx Advanced	Mefenoxam 3.21% Fludioxonil 1.07% Thiamethoxam 21.5%	4 12 Insecticide	*Fusarium* spp., *Pythium* spp., *Phytophthora* spp. *R. solani*	3.1 fl. oz. per cwt.
CruiserMaxx Vibrance	Thiamethoxam 20.8% Mefenoxam 3.13% Fludioxonil 1.04% Sedaxane 1.04%	Insecticide 4 12 7	*Fusarium* spp., *Pythium* spp., *Phytophthora* spp. *R. solani*	3.22 fl. oz. per cwt.
Dynasty	Azoxystrobin 9.6%	11	*Pythium* spp. *R. solani* *Sclerotium rolfsii*	0.153 – 0.459 fl. oz. per cwt.
EverGol Energy SB	Prothioconazole 7.18% Penflufen 3.59% Metalaxyl 5.74%	3 7 4	*Fusarium* spp. Pythium spp. R. solani	1.0 fl. oz per cwt
Evito 480 SC	Fluoxastrobin 40.3%	11	*R. solani* *Sclerotium rolfsii*	0.16 – 0.24 fl. oz. per 1000 ft. row

Table 1 (*continued*). Fungicides available for controlling seedling diseases on soybean.

Product	**Active Ingredient**	**FRAC Code**	**Fungi Controlled**	**Rate**
Headline SC Fungicide	Pyraclostrobin 23.3%	11	*R. solani*	0.1 – 0.8 fl. oz. per 1000 ft. of row
ILEVO Seed Treatment	Fluopyram 49.02%	7	*Fusarium virguliforme (Sudden Death Syndrome)*	2.17 to 3.62 fl. oz. per cwt
Maxim 4FS	Fludioxonil 40.3%	12	*Fusarium* spp. *R. solani*	0.08 – 0.16 fl. oz. per cwt.
Saltro	Pydiflumetofen 41.7	7	*Fusarium virguliforme (Sudden Death Syndrome)*	1.52 fl. oz. per cwt.
Seed Shield Beans	Thiamethoxam 22.6% Mefenoxam 1.7% Fludioxonil 1.12% Azoxystrobin 0.9%	Insecticide 4 12 11	*Pythium spp. Phytopthora spp. R. solani* Seedborne *Phomopis Systemic Downy Mildew*	3.0 fl. oz. per cwt.
Trilex 2000	Trifloxystrobin 7.12% Metalaxyl 5.69%	11 *4*	*Fusarium* spp. *Pythium* spp. *R. solani*	1.00 fl. oz. per cwt.
Vibrance	Sedaxane 43.7%	7	*R. solani*	0.075 – 0.16 fl. oz. per cwt
Vitavax-34 Seed Treatment fungicide	Carboxin 34%	***7***	*R. solani*	3 – 4 fl. oz. per cwt.
Warden RTA	Mefenoxam 2.21 % Fludioxonil 0.72%	4 12	*Pythium spp., Fusarium spp. Phytophthora spp. R. solani*	5.0 fl. oz. per cwt

Do not use treated seed for food, feed, or oil purposes. Do not graze or feed livestock on forage or hay grown from treated soybean seed. All treated seed must be colored with an EPA-approved dye which imparts an unnatural color to the seed to help prevent the inadvertent use of treated seed as food for man or feed for animals.

Table 2. Foliar fungicides for use on soybean in South Carolina.

Product	Active Ingredient	FRAC Code	Rate (fl. oz. /acre)	No. of appl. /year & max. (fl. oz. /acre) /year	Diseases Controlled
Affiance 1.5 SC	Azoxystrobin 9.35% Tetraconazole 7.48%	11 3	10 – 14	3 (28.7)	Rust + other diseases
Aftershock	Fluoxastrobin 40.3%	11	2.7 to 5.7 fl. oz.	2(11.4)	Rust + other diseases
Alto 100SL	Cyproconazole 8.9%	3	2.75 – 5.5	2 (11)	Rust + other diseases
Aproach	Picoxystrobin 22.5%	11	6 – 12	3 (36)	Rust + other diseases
Aproach Prima	Picoxystrobin 17.94% Cyproconazole 7.17%	11 3	5.0 – 6.8	2 (13.6)	Rust + other diseases
Cercobin Fungicide	Thiophanate-methyl 41.3%	1	10.9-21.8	2(43.6)	For other diseases **Will not control rust**
Thiophanate Methyl 85 WDG	Thiophanate-methyl 85%	1	0.4-0.8 lbs./acre	2(1.6 lbs.)	For other diseases **Will not control rust**
TOPSIN 4.5 FL	Thiophanate-methyl 45.0%	1	10-20	2 (40)	For other diseases **Will not control rust**
Topsin M WSB	Thiophanate-methyl 70.0%	1	0.5 – 1.0 lbs./acre	2 (2 lbs.)	Other diseases **Will not control rust**
Acropolis 2.38 F	Thiophanate-methyl 21.27% Tetraconazole 4.20%	1	20 – 23	2(see label)	Rust + other diseases
Froghorn 4.3 SC	Thiophanate-methyl 37.5% tebuconazole 7.5%	1	20	See label	Rust + other diseases
Custodia	Azoxystrobin 11.0% Tebuconazole 18.35%	11 3	8.6	3(25.9)	Rust + other diseases
Domark 230 ME	Tetraconazole 20.5%	3	4 – 5	2 (10)	Rust + other diseases
Andiamo 230 ME	Tetraconazole 20.5%	3	4.0 – 5.0	2(10)	Rust + other diseases
Endura Fungicide	Boscalid 70.0%	7	3.5 – 5.5	2 (22)	Alternaria leaf spot + other diseases. **Will not control rust**
Equation SC	Azoxystrobin 22.8%	11	6.0 – 15.5	2(92.3)	Rust + other diseases
Evito 480 SC	Fluoxastrobin 403%	11	2.0 – 5.7	2 (11.4)	Rust + other diseases
Evito-T Fungicide	Fluoxastrobin 18.0% Tebuconazole 25.0%	11 3	4 – 6	2 (11.4)	Rust + other diseases
Fortix Fungicide	Fluoxastrobin 14.84% Flutriafol 19.30%	11 3	4.0 – 6.0	2 (12)	Rust + other diseases
Preemptor SC Fungicide	Fluoxastrobin 14.84% Flutriafol 19.30%	11 3	4.0 – 6.0	2 (12)	Rust + other diseases
Orius 3.6 F	Tebuconazole 38.7%	3	3.0 – 4.0	3 (12)	Rust + powdery mildew
Tebuzol 3.6 F	Tebuconazole 38.7%	3	3.0 – 4.0	3 (12)	Rust + powdery mildew
Headline SC Fungicide	Pyraclostrobin 23.3%	11	6.0 – 12.0	2 (24)	Rust + other diseases

Table 2 (*continued*). Foliar fungicides for use on soybean in South Carolina.

Product	Active Ingredient	FRAC Code	Rate (fl. oz. /acre)	No. of appl. /year & max. (fl. oz. /acre) /year	Disease Controlled
Priaxor D	Fluxapyroxad 14.33% Pyraclostrobin 28.58% + Tetraconazole 20.5%	7 11 3	4.0 Component A + 4.0 Component B	2 (8-A + 8-B)	Rust + other diseases
Priaxor XEMIUM BRAND FUNGICIDE	Fluxapyroxad 14.33% Pyraclostrobin 28.58%	7 11	4.0 – 8.0	2 (16)	Rust + other diseases
Proline 480 SC	Prothioconazole 41.0%	3	2.5 – 3.0	3 (9)	Rust + Powdery mildew
Miravis Top	Pydiflumetofen 6.9% Difenoconazole 11.5%	7 3	13.7	2(27.5)	Cercospora leaf spot, frogeye, pod & stem blight, target spot
Quadris Flowable	Azoxystrobin 22.9%	11	6 - 15.5	2 (92)	Rust + other diseases
Quadris Top SB	Azoxystrobin 18.2% Difenoconazole 11.4%	11 3	8 – 14	2 (26.5)	Rust + other diseases
Quadris Top SBX	Azoxystrobin 19.8% Difenoconazole 19.8%	11 3	7.0 – 7.5	2 (14.8)	Rust + other diseases
Helmstar Plus SC	Azoxystrobin 11.0% Tebuconazole 22.0%	11 3	7.2	3(21.8)	Rust + other diseases
Brixen Fungicide	Azoxystrobin 13.76% Tetraconazole 6.67%	11 3	13 - 16	2(32)	Rust + other diseases
Quilt Fungicide	Azoxystrobin 7.0% Propiconazole 11.7%	11 3	14 - 20.5	2 (42)	Rust + other diseases
Cover XL	Azoxystrobin 13.5% Propiconazole 11.7%	11 3	10.5 – 21.0	2(42)	Rust + other diseases
Quilt Xcel	Azoxystrobin 13.5% Propiconazole 11.7%	11 3	10.5 – 21.0	2(42)	Rust + other diseases
Revyetek	Mefentrifluconazole 11.61% Fluxapyroxad 7.74% Pyraclostrobin 15.49%	3 7 11	8.5 to 15	2(30)	Rust + other diseases
Stratego	Propiconazole 11.4% Trifloxystrobin 11.4%	3 11	10.0	3(30)	Rust + some other diseases
Stratego YLD	Prothioconazole 10.8 Trifloxystrobin 32.3%	3 11	4.0 -4.65	3(13.95)	Rust + other diseases
Tilt	Propiconazole 41.8%	3	4.0-6.0	2(12)	Rust + other diseases
Topguard FUNGICIDE	Flutriafol 11.8%	3	7.0 – 14.0	2 (14)	Rust + other diseases
Trivapro Fungicide	Bensovindiflupyr 10.27% Azoxystrobin 13.5% Propiconazole 11.7%	7 11 3	20.7	41.4	Rust + other diseases
Veltmya	Mefentrifluconazole 17.56% + Pyraclostrobin 17.56	3 11	7.0 to 10.0	2 (20)	Rust + other diseases
Vertisan	Penthiopyrad 20.6%	7	10 - 30	2 (61)	Rust + other diseases
Zolera FX Fungicide	Fluoxastrobin 17.76% Tetraconazole 17.76%	11 3	4.4 – 6.8	1 (6.8)	Rust + other diseases

[1]*For a list of specific diseases controlled by each fungicide please see a product label.*

COOPERATIVE EXTENSION
College of Agriculture, Forestry and Life Sciences

Table 3. Products containing chlorothalonil for the control of rust and other foliar diseases of soybean.

Product	**Active Ingredient** TwinLine Fungicide	**FRAC Code**	**Rate per acre**	**Maximum total/year**
Bravo Weather Stik	Chlorothalonil 54.0%	M5	1.5-2.25 pts. (2 appl.) 1.0-2.0 (3 appl.)	6.0 pts.
Bravo Ultrex	Chlorothalonil 82.5%	M5	0.9 -1.4 lbs. (3 appl.) 1.4 - 2.2 lbs. (2 appl.)	5.4 lbs.
Echo 720	Chlorothalonil 54%	M5	16 - 32 fl. oz. (3 appl.) 24 - 40 fl. oz. (2 appl.)	96.0 fl. oz.
Echo 90DF	Chlorothalonil 90%	M5	0.875 - 1.62 lbs. (3 appl.) 1.25 - 2.0 lbs. (2 appl.)	4.4 lbs.
Equus 720 SST	Chlorothalonil 54.0%	M5	1.0 - 2.0 pts. (3 appl.) 1.5 - 2.25 pts. (2 appl.)	6.0 pts.
Equus DF	Chlorothalonil 82.5%	M5	0.9 - 1.4 lbs. (3 appl.) 1.4 - 2.1 lbs. (2 appl.)	5.4 lbs.
Arius ADV	Chlorothalonil 44.0% Azoxystrobin 11.6%	M5 11	20 – 25 fl. oz. (2 appl.)	See label
Mazingus ADV	Chlorothalonil 27.69% Tetraconazole 2.09%	M5 3	2 pts. (2 appl.)	See label

Management of Insects in Soybeans

Jeremy K. Greene, PhD

The keys to managing insect pests in soybean are to:

1. Scout fields during high-risk periods for your area.
2. Correctly identify insect pests.
3. Use treatment thresholds to make spray decisions.
4. Use the safest, most economical, and environmentally sound insecticide and rate.
5. Accurately calibrate spray equipment and properly apply insecticides.

Scouting

Check soybeans regularly from early vegetative stages to beginning maturity (R7). If velvetbean caterpillars (mainly the southern Coastal Plain) or stink bugs are a problem in your area, continue scouting until leaves start to shed (into R7). Place a high priority on checking fields in bloom from the last week of July through August. Corn earworm moths are attracted to blooming fields and will lay more eggs in open-canopied beans on high spots and lighter soil areas. Stink bugs can be difficult to scout for because they may not be found in all areas of a field. Stink bug damage can occur from pod set to when pods begin to yellow, but greatest injury occurs during early pod-fill. Because kudzu bugs are stem feeders, they can infest soybeans during any growth stage and should be scouted for regularly. The most important consideration for any field scouting program is to get a representative sample. If it is impossible to scout all fields, at least sample representative varieties and planting dates each week. Do not treat all fields based on what is found in one variety or maturity group.

Check in at least two different accessible areas of a field, such as opposite ends or on a lighter and heavier soil type. In both areas, move in 20 steps and take at least two samples. Take more samples if insect populations are not clearly above or below the treatment threshold level. To take each sample in conventional wide-row spacing, bend one row out of the way and place a 3 ft by 3 ft beat cloth (also called a ground or drop cloth) with dowel handles between the rows. Bend 3 feet of one row over the cloth and beat down vigorously on the soybeans at least 10 times. Move the beans back, and then count and identify insects. Divide by three to get the number of pests per row foot. Shake the cloth off thoroughly before taking another sample.

Soybeans that are drilled require insect scouting and treatment thresholds tailored for use in narrow rows. There are several sampling alternatives, but the most practical involves using a sweep net. Use a 15-inch diameter heavy-duty sweep net such that the upper edge of the net stays even with or slightly below the top of the canopy as you sweep it through the crop. Sweep forcefully with a back-and-forth motion as you walk through the field. Make one sweep with each stride. You actually make an elongated “figure 8” motion with the net; each pass covering two 38-inch rows or the equivalent width of narrow rows. Make 10 sweeps (each pass in either direction counts as a sweep); then count the number of insects in the net, being careful to sort through the leaves in the bottom of the net. Take a minimum of two 10-sweep samples in each of two different areas of the field or more until you are confident of your estimates. Note: Sources of sweep nets include Gempler’s (www.gemplers.com), Forestry Suppliers (www.forestry-suppliers.com), and SweepNets.com (www.sweepnets.com). Buy the heavy-duty 15-inch insect sweep net and order a replacement net.

Defoliation Thresholds

The general defoliation threshold for foliage-feeding pests or pest combinations is 30% leaf-area loss before bloom and 15% thereafter. There is a tendency to overestimate foliage loss, in part because insects often feed in the upper, more visible part of the canopy. In addition, there is a tendency for the eye to focus more on damaged leaves. A technique to “calibrate” or check defoliation estimates is to remove a trifoliate leaf (three leaflets) from the top, middle, and lower part of the canopy without looking. Then take an extra leaflet from the middle canopy, for a total of ten leaflets. Look at each leaflet individually and assign a score of 0 to 10 to each based on an estimate of the portion of leaf area that is missing. For example, a score of 1 requires that at least 10% is missing; a 3 means that

30% is eaten; a 10 indicates that all or nearly the entire leaflet is gone. Add up the score total for all ten leaflets to arrive at a defoliation estimate. Calculate several such defoliation scores and compare the average to estimates made by simply scanning the canopy.

Beat-Cloth Thresholds

The thresholds in table 1 (per row ft) and table 2 (per 3-ft sample) can be used with the beat cloth method.

Table 1. Treatment thresholds (per row ft) for soybean insects sampled with beat cloth.

Pest	Row width (inches)				
	38	30	21	14	7
stink bug	1	0.8	0.5	0.3	0.2
corn earworm*	2	1.6	1.1	0.7	0.4
velvetbean caterpillar	4-6	4	2.7	1.8	0.9
soybean looper	6-8	5.5	3.8	2.6	1.3

*this is the pod-feeding threshold for corn earworm

Table 2. Treatment thresholds (per 3 row ft) for soybean insects sampled with beat cloth.

Pest	Row width (inches)				
	38	30	21	14	7
stink bug	3	2.4	1.6	1.1	0.5
corn earworm*	6	4.7	3.3	2.2	1.1
velvetbean caterpillar	12-18	12	8.3	5.5	2.7
soybean looper	18-24	16	11.6	7.7	3.8

*this is the pod-feeding threshold for corn earworm

Sweep-Net Thresholds

Sweep net thresholds in drilled soybeans are not as well-defined as those for beat/shake samples. The following thresholds should be considered guidelines until more research is available. Use percent defoliation estimates as an additional treatment guideline for foliage feeders. Prior to bloom, up to 30% defoliation is acceptable without economic yield loss, but once blooming begins, the guideline drops to 15% defoliation.

Table 3. Treatment guidelines for soybean insects sampled with a sweep net.

Pest	Number per 10 sweeps	Comments
stink bug	1-2	
corn earworm	3	or 15% foliage loss
velvetbean caterpillar	10	or 15% foliage loss
soybean looper	15	or 15% foliage loss
kudzu bug	10 (nymphs)	1 nymph per sweep

For other foliage feeders, use a threshold of 30% defoliation before first bloom, 15% after first bloom.

Insect Identification

The most common caterpillars found in soybean are the corn earworm, green cloverworm, velvetbean caterpillar, soybean looper, and tobacco budworm (Figure 1). Because color and size are quite variable, the field key below can be helpful in pointing out distinguishing characteristics. The adults are also shown for each species, as identifying moths in the field can provide extra time before a problem appears with caterpillars that will hatch from eggs.

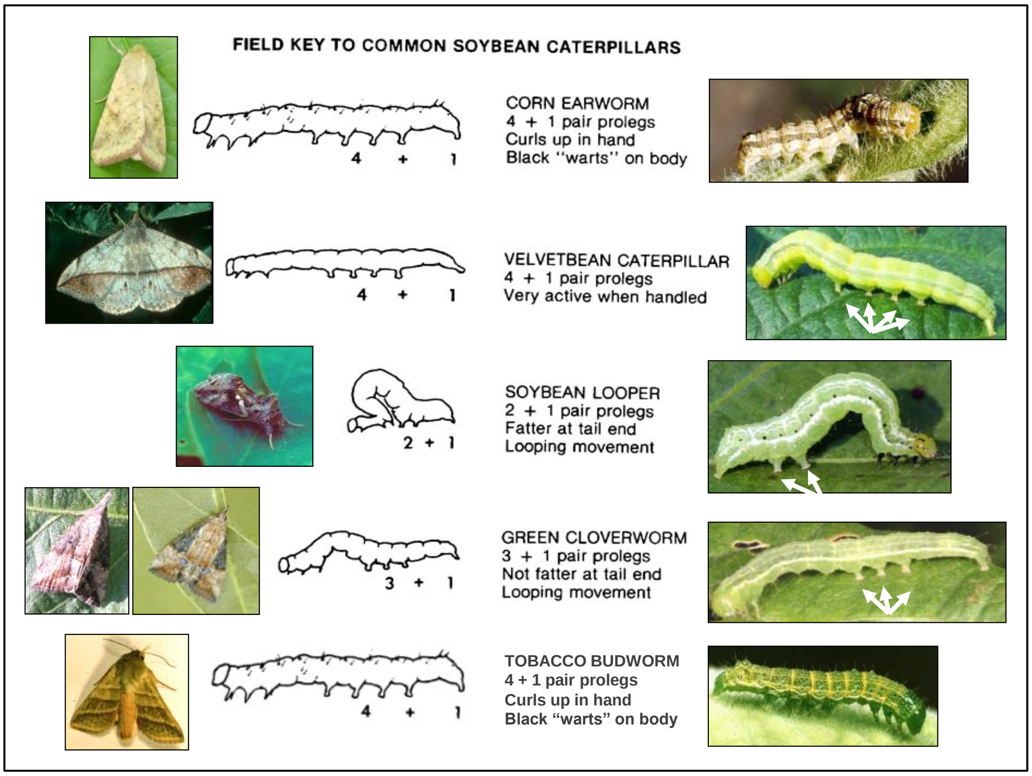

Figure 5. Pictures of common soybean caterpillars.

Corn Earworm (Podworm)

Corn earworms have many color variations, but the presence of dark "warts" and more body "hairs" helps to distinguish smaller larvae from other common soybean leps. Corn earworm also tends to curl up in a C-shape when handled. They have a 4 + 1 proleg pattern, unlike green cloverworms or loopers. The primary infestation period is from the last week of July to early September. Corn earworm, often called "podworm," is a pest throughout the state feeding on foliage, blooms, pods, and terminal stems. Corn earworms and stink bugs are the most economically important pests of soybean because they feed directly on pods.

Velvetbean Caterpillar

4 + 1 pair prolegs (3 + 1 when small); very active when touched; light green to black; causes problems around mid-August to late October; mainly found in southern Coastal Plain, especially Beaufort, Charleston, Colleton, Hampton, and Jasper counties. This late-season pest is often mistakenly called "armyworm" because it seems to appear overnight in large numbers and can rapidly strip a field. The dark color of some specimens also causes confusion. If you see large numbers of very small green worms on the shake cloth late in the season, be on the alert for velvetbean caterpillar defoliation beginning in the top of the canopy.

Soybean Looper

2 + 1 pair prolegs; looping movement; fatter at "tail-end" of body; usually causes problems from mid-August to mid-September, mainly in cotton production areas and southern coastal counties. The three pairs of thoracic (front) legs may be green or black. Leg color can change on the same insect as it ages and has no effect on insecticide

tolerance. This pest prefers plants that are not drought-stressed. Damage usually starts in the middle of a lush canopy.

Green Cloverworm

3 + 1 pair prolegs; looping movement; not fatter at tail-end; can be a problem during July to September; seldom does significant damage by itself, statewide distribution. This insect is often misidentified as a looper due to the looping motion of small larvae. This mistaken identity can be expensive. High rates of pyrethroids and other insecticides are often wasted on cloverworms misidentified as loopers.

Stink Bugs

Green or brown shield-shaped insects as adults, immatures with same general shape, but no wings; mainly an August-September problem; mostly southern Coastal Plain. Stink bug damage is much less obvious than caterpillar damage but usually more costly. Stink bug feeding causes shriveled seed with reduced germination and can cause small pods to abort.

Lesser Cornstalk Borer

Green-blue or purple-banded larvae, up to three-quarters of an inch long; found at soil surface or tunneled into stem; body twitches vigorously when touched; builds a sand tube often found attached to the stem. Can be serious pest during drought stress, particularly on soils with a sandy surface. Burning and disking of wheat stubble prior to planting increases lesser cornstalk borer problems. Reduced tillage reduces lesser cornstalk borer damage. This pest destroys soybean stands by girdling or tunneling into seedlings. The problem is usually misdiagnosed as poor germination or stand loss caused directly by drought stress. The preventative treatment listed under control can protect stands in high-risk situations.

Soybean (Dectes) Stem Borer

Pale gray adults with long black and gray banded antennae. Larvae are cream-colored legless grubs that tunnel stems of soybeans and other hosts (ragweed, cocklebur, etc.). Larval stage is injurious to soybean by tunneling mainstems, producing seriously damaged plants and significant yield loss when infestation is early, resulting in lodged or cut plants. Associated with repetitive monoculture soybean, so crop rotation helps tremendously with prevention. Insecticide sprays are ineffective in controlling larvae or adults, and cultural practices involving crop destruction and land preparation (i.e., disking, deep plowing) are primary modes of control.

Kudzu Bugs

Kudzu bug adults grow to about the same size as adult lady beetles. They have a small, almost square-like appearance, measure approximately one-fourth inch long, and have a light brown color with an olive-green hue and dark specks. Kudzu bug eggs have a light tan color and are laid in a slanting position in two-row masses. Each barrel-shaped egg has a row of spines around the operculum (lid or opening for emerging nymphs). When immature insects hatch from the eggs, they have an orange color and remain in close proximity to the egg mass for a short time before dispersing. As nymphs grow, they take on a paler green color and a very “hairy” appearance, particularly in the late immature stages. When large numbers of adults and/or nymphs exist together, the species has a very distinct odor that can be quite strong, often to the point of being useful in detecting their presence before visually confirming it.

Timing of major soybean pest infestations South Carolina.

<table>
<tr><td colspan="9">Kudzu Bugs, Grasshoppers (all season)</td></tr>
<tr><td colspan="1"></td><td colspan="4">Corn Earworms</td><td colspan="4"></td></tr>
<tr><td colspan="3"></td><td colspan="3">Soybean Loopers</td><td colspan="3"></td></tr>
<tr><td colspan="4"></td><td colspan="4">Stink Bugs</td><td colspan="1"></td></tr>
<tr><td colspan="5"></td><td colspan="4">Velvetbean Caterpillars</td></tr>
<tr><td colspan="2">July</td><td colspan="3">August</td><td colspan="2">September</td><td colspan="2">October</td></tr>
</table>

Chemical and Rate Selection

See the following section for insecticide recommendations. A rate range is usually given for pest control. Factors that influence the required rate are pest size, pest density, plant size, temperature, and application method. The higher rates generally are needed for combinations of heavy populations, larger insects, dense plant canopy, extreme temperatures (95 degrees F), and aerial application.

Use of broad-spectrum insecticides such as Lannate can result in retreatment for late-season velvetbean caterpillar outbreaks. In areas with annual velvetbean caterpillar problems, growers should consider adding Dimilin to corn earworm, stink bug, or boron treatments to prevent retreatment.

Soybean Insect Control

Corn Earworm and Green Cloverworm* (Pyrethroids/Non-Pyrethroids)
Bean Leaf Beetle, Three-cornered Alfalfa Hopper, and Japanese Beetle (Pyrethroids)

Product (pyrethroids)	**Product/acre**	**Lb ai/acre**	**Acre/gal**	**REI**	**PHI**	**Comments**
beta-cyfluthrin **(R)** Baythroid XL 1 EC	1.6-2.8 oz	0.013-0.022	45.7-80	12 hr	45 d	Pyrethroids provide residual activity for VBC. Defoliation should not exceed 15-20% after mid-bloom or 30% before mid-bloom. Consider size of population, canopy density, temperature in selecting rate. After pods appear, treat for 2 or more large (>0.5 in) CEW per row ft. *Use low rates for GCW that infrequently require control. Treat for TCAH when stand is threatened, at 3 per row ft, or more than several/sweep.
lambda-cyhalothrin **(R)** Warrior II 2.08 CS Silencer 1 EC or Lambda-Cy 1 EC	0.96-1.6 oz 1.92-3.2 oz	0.0156-0.026	80-133 40-66.6	24 hr	30 d	
esfenvalerate **(R)** Asana XL 0.66 EC	5.8-9.6 oz	0.03-0.05	13-22	12 hr	21 d	
gamma-cyhalothrin **(R)** Declare 1.25 CS	0.77-1.28 oz	0.0075-0.0125	100-166	24 hr	30 d	
zeta-cypermethrin **(R)** Mustang Max 0.8 EC	2.8-4.0 oz	0.0175-0.025	32-45.7	12 hr	21 d	
zeta-cypermethrin **(R)** + bifenthrin **(R)** Hero 1.24 EC	2.6-6.1 oz	0.025-0.06	21-49.2	12 hr	21 d	
bifenthrin **(R)** Discipline 2 EC or Brigade 2 EC or Fanfare 2 EC	2.6-6.4 oz	0.04-0.1	20-50	12 hr	18 d	
Product (non-pyrethroids)	**Product/acre**	**Lb ai/acre**	**Acre/gal**	**REI**	**PHI**	
indoxacarb Steward 1.25 EC	5.6-11.3 oz	0.054-0.11	11.3-22.8	12 hr	21 d	
spinosad Blackhawk 36 WG	1.7-2.2 oz	0.038-0.05	-	4 hr	28 d	
methomyl **(R)** Lannate 2.4 LV	0.75-1.5 pt	0.225-0.45	5.3-10.7	48 hr	14 d	
carbaryl Sevin 80 S Sevin XLR Plus Sevin 4 F	0.94-1.56 lb 0.75-1.25 qt 0.75-1.25 qt	0.75-1.25	- 3.2-5.33 3.2-5.33	12 hr	21 d	
chlorantraniliprole Prevathon 0.43 SC	14.0-20.0 oz	0.047-0.067	6.25-9.1	4 hr	21 d	5-d interval/ application
methoxyfenozide/spinetoram Intrepid Edge 3	4.0-6.4 oz	0.094-0.15	20-32	4 hr	28 d	Pre-mixed

Thrips

Product	Product/acre	Lb ai/acre	Acre/gal	REI	PHI	Comments
acephate Orthene/Acephate 97 Orthene/Acephate 90	 4.6-8.0 oz 5.0-8.96 oz	0.28-0.5	 - -	24 hr	14 d	Treat only when stand is threatened

Grasshoppers

Product (pyrethroids)	Product/acre	Lb ai/acre	Acre/gal	REI	PHI	Comments
beta-cyfluthrin **(R)** Baythroid XL 1 EC	 2.0-2.8 oz	0.016-0.022	 45.7-64	12 hr	45 d	Grasshoppers can be a problem on soybeans in reduced tillage systems. Eggs are deposited in the soil in pods and are not destroyed in minimum tillage. Re-infestation occurs from field edges and from eggs hatching in fields. High rates of OPs and pyrethroids are needed on larger species. Dimilin, an insect growth regulator (IGR), works only on immatures and should be considered in minimum-tillage fields with a history of problems.
lambda-cyhalothrin **(R)** Warrior II 2.08 CS Silencer 1 EC or Lambda-Cy 1 EC	 1.6-1.92 oz 3.2-3.84 oz	0.026-0.03	 66.6-80 33.3-40	24 hr	30 d	
esfenvalerate **(R)** Asana XL 0.66 EC	 5.8-9.6 oz	0.03-0.05	 13-22	12 hr	21 d	
gamma-cyhalothrin **(R)** Declare 1.25 CS	 1.28-1.54 oz	0.0125-0.015	 83-100	24 hr	30 d	
zeta-cypermethrin **(R)** Mustang Max 0.8 EC	 3.2-4.0 oz	0.02-0.025	 32-40	12 hr	21 d	
bifenthrin **(R)** Discipline 2 EC or Brigade 2 EC or Fanfare 2 EC	 2.6-6.4 oz	0.04-0.1	 20-50	12 hr	18 d	
zeta-cypermethrin **(R)** + bifenthrin **(R)** Hero 1.24 EC	 2.6-6.1 oz	0.025-0.06	 21-49.2	12 hr	21 d	
Product (non-pyrethroids)	**Product/acre**	**Lb ai/acre**	**Acre/gal**	**REI**	**PHI**	
acephate Orthene/Acephate 97 Orthene/Acephate 90	 4.6-8.0 oz 5.0-8.96 oz	0.28-0.5	 - -	24 hr	14 d	
carbaryl Sevin 80 S Sevin XLR Plus or Sevin 4 F	 0.94-1.56 lb 0.75-1.25 qt	0.75-1.25	 - 3.2-5.33	12 hr	21 d	
chlorpyrifos **(R)** Lorsban 4 E or Chlorpyrifos 4 E or Nufos 4 E Lorsban Advanced 3.755	 1.0-2.0 pt 0.5-1.0 pt	0.23-1.0 0.5-1.0 0.23-0.47	 4-8 8-16	24 h	28 d	
diflubenzuron Dimilin 2 L **(R)**	 2.0 oz	0.03125	 64	12 hr	21 d	Effective on nymphs only

Spider Mites

Product	Product/acre	Lb ai/acre	Acre/gal	REI	PHI	Comments
dimethoate Dimethoate 4 EC	 1.0 pt	0.5	 8	48 hr	21 d	Can be a problem in drought stress

Velvetbean Caterpillar

Product (pyrethroids)	Product/acre	Lb ai/acre	Acre/gal	REI	PHI	Comments
beta-cyfluthrin **(R)** Baythroid XL 1 EC	 1.6 oz	0.0125	 80	12 hr	45 d	VBC occurs in high numbers but is easily controlled. Use higher rates for high populations. Significant defoliation can be caused by 4-6 large VBC per row ft, and pod clipping can occur after defoliation. Treat when defoliation exceeds 15% after mid-bloom and at 30% before mid-bloom. Pyrethroids can provide extended residual control of VBC. Dimilin is a preventative treatment for high-risk areas.
lambda-cyhalothrin **(R)** Warrior II 2.08 CS Silencer 1 EC or Lambda-Cy 1 EC	 0.96 oz 1.92 oz	0.0156	 133 66.6	24 hr	30 d	
esfenvalerate **(R)** Asana XL 0.66 EC	 2.9 oz	0.015	 44	12 hr	21 d	
gamma-cyhalothrin **(R)** Declare 1.25 CS	 0.77 oz	0.0075	 166	24 hr	30 d	
zeta-cypermethrin **(R)** Mustang Max 0.8 EC	 2.8 oz	0.0175	 45.7	12 hr	21 d	
zeta-cypermethrin **(R)** + bifenthrin **(R)** Hero 1.24 EC	 2.6-6.1 oz	0.025-0.06	 21-49.2	12 hr	21 d	
Product (non-pyrethroids)	**Product/acre**	**Lb ai/acre**	**Acre/gal**	**REI**	**PHI**	
methoxyfenozide Intrepid 2 F	 4.0 oz	0.0625	 32	4 hr	14 d	
diflubenzuron Dimilin 2 L	 2.0-3.0 oz	0.03125-0.047	 42.6-64	12 hr	21 d	
spinosad Blackhawk 36 WG	 1.1-2.2	 0.025-0.05	 -	4 hr	28 d	
methomyl **(R)** Lannate 2.4 LV	 4.8-9.6 oz	0.09-0.18	 13.3-26.6	48 hr	14 d	
carbaryl Sevin 80 S Sevin XLR Plus or Sevin 4 F	 0.5-1.0 lb 1.0-1.5 pt	0.5-0.75	 - 5.33-8.0	12 hr	21 d	
chlorantraniliprole Prevathon 0.43 SC	 14.0-20.0 oz	0.047-0.067	 6.25-9.1	4 hr	21 d	5-d interval/ application
methoxyfenozide/spinetoram Intrepid Edge 3	 4.0-6.4 oz	0.094-0.15	 20-32	4 hr	28 d	 Pre-mixed

Soybean Looper, Tobacco Budworm, Beet and Fall Armyworm

Product	Product/acre	Lb ai/acre	Acre/gal	REI	PHI	Comments
indoxacarb Steward 1.25 EC	5.6-11.3 oz	0.054-0.11	11.3-22.8	12 hr	21 d	See CEW defoliation thresholds. It takes 6-8 large loopers per row ft to cause major defoliation. ***Not for TBW.**
spinosad Blackhawk 36 WG	1.1-2.2	0.025-0.05	-	4 hr	28 d	
methoxyfenozide Intrepid 2 F*	4.0-8.0 oz	0.0625-0.125	16-32	4 hr	14 d	
chlorantraniliprole Prevathon 0.43 SC	14.0-20.0 oz	0.047-0.067	6.25-9.1	4 hr	21 d	3-d interval/ application
methoxyfenozide/spinetoram Intrepid Edge 3	4.0-6.4 oz	0.094-0.15	20-32	4 hr	28 d	Pre-mixed

Stink Bugs

Product (pyrethroids)	Product/acre	Lb ai/acre	Acre/gal	REI	PHI	Comments
beta-cyfluthrin **(R)** Baythroid XL 1 EC	1.6-2.8 oz	0.013-0.022	45.7-80	12 hr	45 d	After pods appear, treat when stink bugs reach 1 per row ft using a drop cloth or 1-2 per 10 sweeps using a sweep net. Treat for stink bugs exceeding threshold into R7. Redbanded stink bugs (RBSB) are more difficult to control. Use mix of pyrethroid and acephate for redbanded stink bug. Orthene might increase chances for later problems with SBL or VBC
lambda-cyhalothrin **(R)** Warrior II 2.08 CS Silencer 1 EC or Lambda-Cy 1 EC	1.6-1.92 oz 3.2-3.84 oz	0.026-0.03	66.6-80 33.3-40	24 hr	30 d	
gamma-cyhalothrin **(R)** Declare 1.25 CS	1.28-1.54 oz	0.0125-0.015	83-100	24 hr	30 d	
zeta-cypermethrin **(R)** Mustang Max 0.8 EC	3.2-4.0 oz	0.02-0.025	32-40	12 hr	21 d	
zeta-cypermethrin **(R)** + bifenthrin **(R)** Hero 1.24 EC	4.0-10.3 oz	0.04-0.1	12.4-32	12 hr	21 d	
bifenthrin **(R)** Discipline 2 EC or Brigade 2 EC or Fanfare 2 EC	2.6-6.4 oz	0.04-0.1	20-50	12 hr	18 d	
alpha-cypermethrin **(R)** Fastac 0.83 EC	3.8 oz	0.025	33.7	12 hr	21 d	
Product (non-pyrethroids)	**Product/acre**	**Lb ai/acre**	**Acre/gal**	**REI**	**PHI**	
acephate Orthene/Acephate 90 Orthene/Acephate 97	 9.6-16.0 oz 8.0-16.0 oz	0.5-1.0	 - -	24 hr	14 d	

Lesser Cornstalk Borer

Product	Product/acre	Lb ai/acre	Acre/gal	REI	PHI	Comments
chlorpyrifos **(R)**		1.0-2.0		24 h	7 d	PREVENTION: Reduced tillage significantly reduces LCB damage, as does early season irrigation. AT PLANTING: Apply 8-15 oz 15G/1000 row ft (38' rows) in 6- 8-inch band over row. Incorporate lightly with press wheel and drag chain or tines. RESCUE (erratic): When 10% of seedlings show damage, apply 4E in 25 gal water in 6-inch band directly at the base of plant.
Lorsban 15 G	6.7-13.3 lb		-			
chlorpyrifos **(R)**		0.47-1.0			28 d	
Lorsban 4 E or				24 h		
Nufos 4 E or						
Chlorpyrifos 4 E	1.0 qt	1.0	4			
Lorsban Advanced 3.755	0.5-1.0 qt	0.47-0.94	4-8			

Kudzu Bugs

Product (pyrethroids)	Product/acre	Lb ai/acre	Acre/gal	REI	PHI	Comments
bifenthrin **(R)**		0.0625-0.1		12 hr	18 d	Apply insecticide when sweep-net sampling yields one nymph per sweep. If kudzu bug immatures are easily and repeatedly found on petioles and main stems during visual inspections of the canopy, treatment is likely warranted. Do not bias all sampling to border rows where initial populations build. Border treatment for initial infestations of adults limited to field edges might delay need for whole-field treatment.
Discipline 2 EC	4.0-6.4 oz		20-32			
Brigade 2 EC	4.0-6.4 oz		20-32			
Fanfare 2 EC	4.0-6.4 oz		20-32			
lambda-cyhalothrin **(R)**		0.03		24 hr	30 d	
Warrior II 2.08 CS	1.92 oz		66.6			
Silencer 1 EC	3.84 oz		33.3			
gamma-cyhalothrin **(R)**		0.015		24 hr	30 d	
Declare 1.25 CS	1.54 oz		83			
zeta-cypermethrin **(R)**		0.025		12 hr	21 d	
Mustang Max 0.8 EC	4.0 oz		32			
zeta-cypermethrin **(R)** + bifenthrin **(R)** Hero 1.24 EC	6.4-10.3 oz	0.062-0.1	12.4-20	12 hr	21 d	
alpha-cypermethrin **(R)**		0.025				
Fastac 0.83 EC	3.8 oz		33.7	12 hr	21 d	
Pre-mixed products containing a pyrethroid listed here and another active ingredient with activity on kudzu bugs (see Multiple Pests – Pre-Mixed Products below)						

Multiple Pests – Pre-Mixed Products

Product	Product/acre	Lb ai/acre	Acre/gal	REI	PHI	Comments
thiamethoxam/*lambda*-cyhalothrin **(R)** Endigo 2.06 ZC	2.5-4.5 oz	0.04-0.072	28.4-51.2	24 hr	30 d	Season limit of 9 oz/acre Pre-mixed
imidacloprid/*beta*-cyfluthrin **(R)** Leverage 360	2.8 oz	0.0656	45.7	12 hr	14 d	Pre-mixed
imidacloprid/bifenthrin **(R)** Brigadier 2 SC	5.1-6.1 oz	0.08-0.095	21-25	12 hr	18 or 45 d	Pre-mixed
chlorpyrifos/*lambda*-cyhalothrin **(R)** Cobalt Advanced 2.63	11.0-38.0 oz	0.226-0.78	3.4-11.6	24 hr	30 d	Pre-mixed
chlorantraniliprole/*lambda*-cyhalothrin **(R)** Besiege 1.25 ZC	5.0-10.0 oz	0.049-0.098	12.8-25.6	24 hr	30 d	Season limit of 20 oz/acre Pre-mixed
chlorantraniliprole/bifenthrin **(R)** Elevest 2.22 SC	6.9-9.6 oz	0.12-0.167	13.3-18.5	12 hr	21 d	Pre-mixed
methoxyfenozide/spinetoram Intrepid Edge 3	4.0-6.4 oz	0.094-0.15	20-32	4 hr	28 d	Pre-mixed

Pre-mixed products	Pests and Activity of Product (does not imply good control…just activity)									
	LCB	VBC	TCAH	BAW/FAW	CEW	TBW	SBL	GCW	SB	KB	Grasshoppers
Leverage	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Endigo	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Brigadier	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Besiege	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Elevest	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cobalt Adv	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Intrepid Edge	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	No

For control of multiple pests exceeding thresholds, including but not limited to various combinations of the following: cutworm, cabbage looper, green cloverworm (GCW), corn earworm (CEW), saltmarsh caterpillar, aphids, threecornered alfalfa hopper (TCAH), velvetbean caterpillar (VBC), bean leaf beetles, grasshoppers, plant bugs, kudzu bug (KB), and stink bugs (SB). Use higher rates for stink bugs, corn earworm, and grasshoppers.

ai = active ingredient; (R) = Restricted use; REI = re-entry interval; PHI = pre-harvest interval

Soybean Harvest

Michael Plumblee, PhD

When harvest is delayed due to bad weather, or when some varieties dry down to seed moisture levels below 11%, seed shattering may occur in the field or at the cutter bar at harvest. To reduce the potential for shattering losses, harvest should begin at seed moisture levels of 14% to 12%. If storage bins have the capacity for drying with air blowers, harvesting at 16% is not out of the question. In fact, for most years in South Carolina, those farmers who wait for ideal moisture around 12% often have difficulty in harvesting their entire crop without losses in yield and quality, either from shattering, lodging, or disease. Timely harvest is essential in obtaining maximum yield and a high-quality crop. Significantly reduced yield and quality may be expected if harvest of maturity group IV is delayed due to unfavorable weather conditions.

Lodging, plants falling over, can occur at any time after first bloom and is usually more of a problem with broadcast or drilled plantings. Early lodging can reduce yields by interfering with pod set and pod fill or by encouraging more pod and stem disease problems. Late lodging, such as after a storm with heavy winds, can reduce yields and seed quality because of harvest difficulties and/or improper drying down of the crop. Tall, late-maturing varieties, soybean planted at higher than optimum seeding rates, or soybeans planted in highly fertile bottomland have a higher risk of losses due to lodging. Farmers who anticipate a problem with lodging should select varieties with strong upright stalks or main stems (usually the shorter varieties in Groups V and VI). Additionally, using the proper seeding rate for the row spacing will assist in reducing losses from lodging (see the Planting Considerations section). If excellent growing conditions are expected, seeding rates can further be reduced to ensure crop standability.

To estimate the soybean yield prior to harvest (calculate loss or storage needs, insurance purposes, etc.):

- Count the number of plants from 10 randomly selected rows to get the average plant number. For example, count plants in 14’ 6” long rows for 36-inch-wide rows or 13’ 9” long rows for 38-inch row spacing (1/1000 of the acre) (table 1). Calculate the average and multiply by 1000 (this is your plant population per acre).
- Count the number of pods per plant from 10 randomly selected plants and calculate the average.
- Multiply the plant population per acre by average number of pods per plant to get the number of pods per acre.
- Multiply the number of pods per acre by 2.5 (avg. number of seeds per pod or use your own number) to get the number of seeds per acre.
- Divide the number of seeds per acre by 2500 (or known number of seeds per pound for the variety) to get weight in pounds per acre.
- Divide the weight in pounds per acre by 60 to get yield in bushels/acre.

Table 1. Row spacing and row length for 1/1,000 acre.

Row spacing (inches)	Row length (1/1,000 acre)
15	34 ft. 10 inches
20	26 ft. 2 inches
22	23 ft. 9 inches
28	18 ft. 8 inches
30	17 ft. 5 inches
36	14 ft. 6 inches
38	13 ft. 9 inches
40	13 ft. 1 inch

Soybean Drying and Storage

Aaron P. Turner, PhD and Ryan H. Dean

Drying and storage are essential components of maintaining soybean quality, and understanding these factors is instrumental in reducing production costs and maximizing returns. In order to minimize seed damage (e.g., breaking and splits) and losses, soybeans should be harvested in the range of 15% to 13% but for facilities with drying capabilities beginning at 16% to 17% is not unreasonable (Hurburgh, 2008). At higher moisture contents, soybeans can be difficult to harvest, but at lower moisture contents, damage can increase.

Storage Conditions

To reduce quality degradation and provide safe long-term storage, it is important to cool and dry the grain quickly after harvest. The desired final moisture content depends on the application. The general soybean market moisture is 13.0%, so if the soybeans are sold directly or stored for a short period, the moisture content should be as close to this value as possible to maximize the weight of soybeans sold while avoiding drying charges (see the discussion of moisture shrink below). However, storage times are greatly increased at lower moisture contents of 10% to 12%.

At temperatures below 40°F, insect activity is greatly reduced, and when the relative humidity (RH) in the air space between beans is below 65%, mold growth is significantly reduced (MWPS-13, 2017). Figure 1 shows the relationship between soybean moisture content, temperature, and relative humidity. Conditions that fall below the 65% RH line shown would generally have reduced mold growth. An estimate of the allowable storage time at various temperature and moisture combinations is shown in table 1.

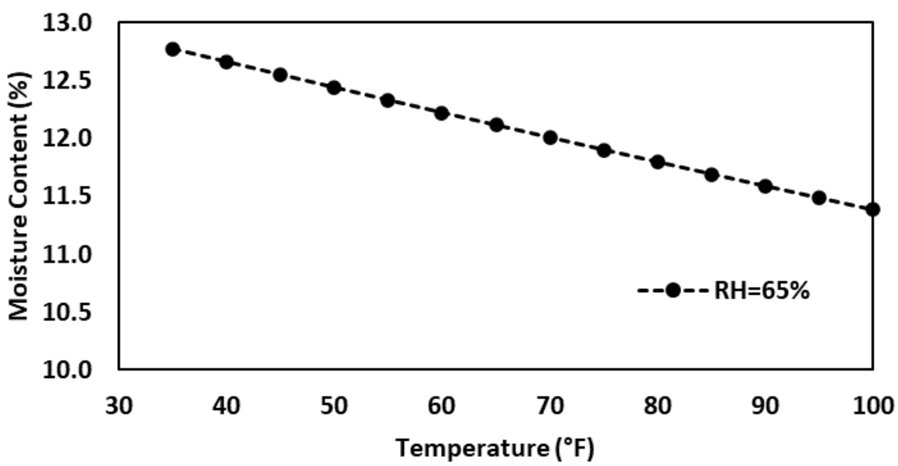

Figure 6. Figure 4: Equilibrium moisture content for soybeans as a function of temperature. Based on data from ASAE Data D245.6 using the Mod. Halsey Equation.

Table 1. Allowable Storage Time (days).*

Temperature	Moisture Content							
°F	11%	12%	13%	14%	15%	16%	17%	18%
30	*	*	*	*	*	*	*	240
40	*	*	*	280	200	140	90	70
50	*	*	230	130	90	70	50	40
60	*	240	120	75	50	35	25	20
70	200	125	70	45	30	20	14	11
80	140	70	40	20	15	10	7	5

*Adapted from McNeill (2018) and Sadaka (2014). An asterisk (*) represents an allowable storage time >300 days. This is based on 0.5% dry matter loss, which corresponds approximately one grade number loss. These effects are cumulative, 10 days at 16% and 70°F would use one-half of the allowable storage time.

Moisture Shrink

Market moisture for soybeans is 13.0%. While moisture is not a grade factor, it influences many qualities, and when beans above this level are sold, a shrink factor is used to adjust the weight of the soybeans to the equivalent weight at 13%. However, there is no "expansion factor" to adjust the weight of soybeans upward if sold below 13%. Because of this, soybeans sold below 13% are inherently less profitable. There is roughly a 1.15% loss per point of moisture below market level.

When producers evaluate marketing locations, they should not only evaluate price per bushel but also drying and shrink charges. In addition to moisture shrink, buyers often include a drying charge and potentially calculate shrink slightly different. Equation 1 and equation 2 can be used to calculate shrink and find the equivalent number of 13% bushels. Assuming no handling loss, the number of adjusted bushels shrinks by roughly 1.15% per point of moisture removed.

$$Shrink = \frac{Mi - Mf}{100 - Mf} + handling\ loss \quad (1)$$

$$Adjusted\ bushels = Wet\ bushels * (1 - shirnk) \quad (2)$$

Example: 1,000 wet bushels are harvested at a moisture content of 15.5%. To adjust to bushels at 13%, assuming no handling loss, moisture shrink is calculated as:

Shrink = (15.5-13) / (100-13) + 0 = 0.0287 or 2.87%

To adjust the number of bushels you have:

*Adjusted bushels = 1000 * (1-.0287) = 971 bu*

Equilibrium Moisture Content

Given enough time, grain moisture will come to equilibrium with ambient conditions (temperature and relative humidity). This is referred to as equilibrium moisture content (EMC), and it can be used as an indicator of how grain moisture will fluctuate in the field during late-season harvest or when drying in a bin using natural air. If EMC, based on ambient conditions, is lower than the grain moisture, drying will occur. If EMC is higher than the current moisture, rewetting occurs (although much slower than drying). For more information on EMC, see the link below to Clemson's equilibrium moisture content calculator.

On-Farm Drying

Drying and cooling the soybeans allows them to reach the safe storage conditions listed above. When drying in a bin, ambient (or slightly heated) air is blown through the grain mass. As the air moves through the soybeans, moisture is transferred from the soybeans to the air. The added moisture reduces the air's drying potential and results in a drying front several feet wide moving through the soybeans in the airflow direction. Generally, this results in the driest (and potentially overdried) soybeans near the bottom of the bin.

When using natural air or low-temperature drying, several options for fan control can be utilized. These include continuous operation, automatic control using sensors in the grain, and manual scheduling. The theme behind alternate operation strategies is to run the fans only when productive air is available, reducing electric costs. Consideration should be given to if the soybeans can be dried, cooled, or, if over dry, rewetted. For more reference information relating to natural air and low-temperature drying, visit these publications from The University of Arkansas and North Dakota State University.

Drying times are dependent on airflow rate, initial moisture content, target moisture content, and EMC. Most operations can dry soybeans in bins using natural air drying. However, when humidity increases above 80%, a small amount of heat may need to be added (5 to 10 degrees) to reduce the EMC of the drying air below the soybean's EMC. Many operations have systems sized and designed for corn, and these fans will produce higher airflow volumes because there is roughly 25% less resistance resulting in faster drying (Hurburgh, 2008). Typical airflow volumes needed for drying are between 1 to 3 cfm per bushel but vary depending on bin diameter and soybean depth. Your supplier should be able to assist with recommending fans, but for more information, see this fan selection tool from the University of Minnesota.

Additional Tips

- Core/level the bin before drying to improve drying uniformity. Uneven surfaces and fines that accumulate in the center of the bin increase static pressure in those areas, resulting in uneven drying.
- Depth of fill impacts airflow and how fast the soybeans will dry. Use the fan calculator above to see how airflow changes with depth.
- Soybeans can also be dried using high-temperature dryers, but retention time in the dryer should be limited to 30 minutes, and drying temperature should be reduced to around 130°F to 140°F for commercial beans (Sadaka, 2014).

Soybean Grading

Soybean grades are determined based on the percentage of damaged kernels (heat damage and total), splits, foreign material, and soybeans of other colors. Soybean grade requirements from the Federal Grain Inspection service are given in table 2 below.

Table 2. Soybean Grades (USDA, 2013).

Grade	Maximum Limits of -				
	Damaged Kernels		Foreign Material (%)	Splits (%)	Beans of other colors[1] (%)
	Heat Damage (% of total)	Total (%)			
U.S. No. 1	0.2	2.0	1.0	10.0	1.0
U.S. No. 2	0.5	3.0	2.0	20.0	2.0
U.S. No. 3	1.0	5.0	3.0	30.0	5.0
U.S. No. 4	3.0	8.0	5.0	40.0	10.0

U.S. Sample Grade is Soybeans that:

A. Do not meet the requirements for grades U.S. No. 1, 2, 3, or 4; or
B. Contains 2 or more stones which have an aggregate weight in excess of 0.1 percent of the sample weight, 1 or more pieces of glass, 3 or more crotalaria seeds (*Crotalaria spp.),* 2 or more castor beans (*Ricinus communis L.*), 4 or more particles of an unknown foreign substance(s), 10 or more rodent pellets, bird droppings, or an equivalent quantity of other animal filth in 1,000 grams of soybeans, or
C. Contain 11 or more animal filth, castor beans, crotalaria seeds, glass, stones, or unknown foreign substance(s) in any combination, or
D. Have a musty, sour, or commercially objectionable foreign odor (except garlic odor); or
E. Are heating or otherwise distinctly low quality.

[1] Disregard for Mixed Soybeans

Aeration

Aeration is a key factor in storing soybeans, and it is important to remove the field heat quickly after harvest. Generally, keeping grain within 10 to 15 degrees of ambient conditions and running air frequently throughout the storage period will help counteract moisture migration.

Monitoring

Monitoring grain condition can simply be smelling grain when first activating fans and watching for crusting or as complex as using sensors to monitor grain and automatically control fans. One of the cheapest ways to monitor grain condition is with temperature cables, which allow for the detection of temperature increases indicating insect, mold, or spoilage problems. These can be combined with RH sensors to estimate moisture content.

Safety

In 2019 grain entrapment led to 23 fatalities (Cheng et al., 2020). Know the dangers associated with entering bins, grain handling equipment, and dust exposure. For more information on safety around grain facilities, see this Clemson's Grain Facility Safety Fact Sheet

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Farm-Stored Soybean Insect Management

Michael Plumblee, PhD

The quality of farm-stored soybeans is at its peak when it is loaded into the bin for storage. After this point, the best you can do is to try to maintain this level of quality. Therefore, it is important to maximize the quality of the beans prior to storage. At harvest, make sure that your beans are dry enough for storage and that your harvesting equipment is adjusted to minimize breaking or cracking the beans.

Only load soybeans into a thoroughly-cleaned, empty bin. Don't load beans on top of older beans! When you load soybeans into the storage bin, make sure your loading auger and mechanical spreaders in the bin are in good condition and will not damage the beans. Run the auger at full capacity (run at a slow speed) to minimize breaking beans. The cleaner and drier the beans are going into the bin, the better.

Do not overfill the bin. Level the beans in the bin as soon as it is filled and immediately begin aeration to cool the beans. Poorly controlled temperatures are the most important cause of stored soybeans going out of condition. Get the beans cooled down to the outside air temperature as soon as possible. Keep the bin temperature no more than 10°–15°F of the outside temperature during storage. Ideally, the temperature should be maintained at 35°–40°F as soon as is possible.

Proper harvest, loading, and storage of soybeans is critical for managing potential insect infestations. Proper storage management provides the best control for the cost. In any insect management system, it is important not to rely on insecticides. This is particularly true for stored grains, as there are few insecticides registered in this area and fewer still for soybeans. Also, insecticide resistance has already made at least malathion essentially useless in many stored grains environments.

Insects will stop feeding and reproduction at temperatures below about 50°F. Because soybeans are held at moisture levels that will not allow mold growth, properly cooled and dried soybeans tend only to be infested by Indian meal moths. This moth infests the grain starting from the top of the bin. The Indian mean moth (adults only) can be controlled using DDVP (dichlorvos) resin strips in the headspace of the bin. Using 1 strip per 1,000 cubic feet. Change strips monthly. You may alternatively, or also, use a Bacillus thuringiensis (Bt) product (for example, Dipel) as a top dressing (grain surface treatment), applied immediately after bin loading (controls larvae only.) Diatomaceous earth products may also be used here, but monthly treatments will be needed.

Because properly loaded and stored soybeans tend to suffer fewer insect infestations than other grains, while bins must be thoroughly cleaned, it may not be necessary to treat bins (bin surface treatment) before loading soybeans, to treat or beans (grain protectant) when loading. In fact, few are registered for these uses. While soybeans are less prone to insect infestations, you must still regularly check the beans - check storage temperature and moisture levels and for flying moths and surface crusting in the top of the bin.

These recommendations are based on active ingredients. These recommendations are not a substitute for carefully reading the pesticide label. Other registered products not mentioned here may be as effective.

Pest or Application Type	Active Ingredient(s) (Products)	Rates *Read and follow the label instructions.*	Site(s)	Comments (*And see Notes after this table*)
Bin Repair & Sanitation			Interior *and* exterior of grain storage bins prior to loading.	*Sanitation is critical.* Repair (fix and fill holes, cracks) and *thoroughly* clean bins before loading with grain. Most pesticide product labels note sanitation as a pre-treatment procedure!
Empty Bin Residual Sprays (Bin interior surface treatment)	Diatomaceous earth (DE) (Insecto)	1 lb./1,000 sq.ft. of surface	Empty bins	Applied through aeration fan. May meet organic requirements.
Grain Top-Dressing (Stored grain surface treatment, especially for Indian-meal moth larvae- *Applications are to leveled grain*)	*Bacillus thuringiensis* (*Bt*) (Biobit HP, Dipel DF, Javelin WG) Diatomaceous earth (DE) (Insecto)	1 lb./10-20 gal. water/1,000 sq.ft.; see label 4 lbs./1,000 sq.ft.	READ THE LABEL FIRST	Apply to surface and rake into top 4 inches of grain; see label instructions. Controls only larvae. May meet organic requirements. Especially for Indian-meal moth. May require second application for heavy infestation. Apply at monthly intervals. May meet organic requirements.

Note: **Product use sites** - Read the label carefully! Use sites vary widely from product to product. Some products may only be used to treat grain storage bin surfaces and not grain; few products may be used for both applications. Grains that may be treated vary with product.

Note: **Product rates** - Read product labels carefully! Rates vary with formulation of product used, use site/crop being stored, anticipated storage time, and pest species, and pest development stage. Some products may only have one (1) application made to a load. Period of control can vary with pest insect species and is shortest at the lowest rates.

Note: **Pests controlled** - Read the label. Not all products control all pests, especially at the lowest rates. Bacillus thuringiensis (Bt) products control only caterpillars (moth larvae) and not beetle grubs. Control will be slow.

Note: **Insecto (a diatomaceous earth product)** - "Insecto Control Plan" calls for dusting the empty bin, treating the bottom 2 feet of grain, treating the top 2 feet of grain, top-dressing leveled grain with this product at labeled rates. Inspect grain bi-weekly. Organic Materials Review Institute (OMRI) Listed.

Note: **Fumigants** are the most effective way of controlling insect infestations in stored grain; however, fumigants provide no residual control. Fumigants are Restricted Use Pesticides (RUPs) and may be purchased and used only by licensed applicators. These pesticides are Danger, Danger/Poison labeled because of acute toxicity. Fumigants have strict application requirements via the label and applicator manual. Product-specific training and/or product company supervision may be required, especially for liquid and gas formulations.

Note: **Malathion** is not recommended because of pest resistance and tolerance issues in international markets.

Grain Bin Surface Areas and Capacities

Bin Diameter (Feet)	Grain Surface Area or Bin Floor Area (Square Feet)	Approximate Surface Area of Empty Bin (Square Feet)	Bushels per Foot of Bin Height	Approximate Bin Headspace (Volume of a cone - Cubic Feet)
15	177	(Bin Height x 47) + 354	141	59 x cone height
18	254	(Height x 57) + 508	204	85 x cone height
21	346	(Height x 66) + 692	277	115 x cone height
24	452	(Height x 75) + 900	362	151 x cone height
27	573	(Height x 85) + 1146	458	191 x cone height
30	707	(Height x 92) + 1400	566	236 x cone height
33	855	(Height x 104) + 1710	685	285 x cone height
36	1,018	(Height x 113) + 2000	815	339 x cone height
42	1,385	(Height x 132) + 2770	1109	462 x cone height
48	1,810	(Height x 151) + 3,620	1448	603 x cone height
54	2,290	(Height x 170) + 4580	1833	763 x cone height
60	2,827	(Height x 188) + 5654	2263	942 x cone height

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